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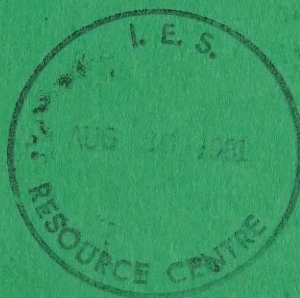
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WATER AND WASTE MANAGEMENT IN THE CANADIAN MEAT AND
POULTRY PROCESSING INDUSTRY, 1981.

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Water and Waste Management in the Canadian Meat and Poultry Processing Industry



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Economic and Technical Review
Report EPS 3-WP-81-3

Water Pollution Control Directorate
June 1981

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WATER AND WASTE MANAGEMENT IN THE CANADIAN MEAT AND POULTRY PROCESSING INDUSTRY

by

Stanley Associates Engineering Ltd.
and
Dearborn Environmental Consulting Services

for

Meat Hygiene Directorate
Food Production and Inspection Branch
Agriculture Canada

and the

Water Pollution Control Directorate
Environmental Protection Service
Environment Canada

Report No. EPS 3-WP-81-3
June 1981

REVIEW NOTICE

This report has been reviewed by the Water Pollution Control Directorate, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

ABSTRACT

This investigation was initiated jointly by Agriculture Canada and Environment Canada to:

- 1) document existing and potential methods of water and waste conservation applicable to Canadian meat and poultry processing operations; and
- 2) demonstrate practical and economical methods for in-plant control of water use and waste loadings in Canadian meat and poultry processing plants.

Subsequent to visits to Canadian and American meat and poultry processing plants to evaluate existing water and waste management practices, demonstration studies were conducted at two Canadian red meat processing facilities and two Canadian poultry processing facilities to document the feasibility of in-plant control of water use and process effluent waste loadings. These studies confirmed that water use and waste load reductions could be accomplished at minimal cost.

In the red meat processing plants, the major areas of water use reduction involved shroud washing processes, employee handwashers, carcass washers and viscera table washing systems. In the poultry processing plants, major reductions were accomplished in the water use associated with coop washing, feather transport, gooseneck handwashers and rotary screen backwashing.

Considerable reductions in process effluent waste loadings were demonstrated at both red meat packing plants, primarily by improving the blood recovery systems. The process effluent BOD₅ was reduced from 48 to 56 percent in these instances. There was no significant decrease in the waste loads at either of the two poultry processing plants.

All process modifications were reviewed by Agriculture Canada and plant inspection staff prior to installation and evaluated during the studies to ensure that no detrimental effect on product quality resulted. The maximum cost of any single modification installed as a result of the demonstration studies was \$7 700 for a blood recovery system at one of the red meat packing plants. The average cost of all other modifications was approximately \$500. Several changes were implemented at no cost. At all four plants, the costs of the modifications could be recovered in less than one year.

The site-specific nature of water use patterns and facilities at a particular plant was determined to be an important factor in identifying the modifications that can be successfully implemented. A number of reuse/recycle schemes which require further study were also identified.

RÉSUMÉ

L'étude a été entreprise à la fois par Agriculture et par Environnement Canada afin:

- 1) de réunir des renseignements sur les moyens actuels et possibles d'économiser l'eau et de récupérer les rejets dans les abattoirs de bétail et de volaille;
- 2) de faire la démonstration des méthodes pratiques et peu coûteuses pour l'emploi d'eau industrielle et la réduction des rejets dans les abattoirs de bétail et de volaille au Canada.

Suite à la visite d'abattoirs canadiens et américains pour y évaluer les méthodes de gestion de l'eau et des déchets, des démonstrations ont été réalisées dans deux abattoirs de volaille et deux de bétail, au Canada, pour confirmer la possibilité d'y économiser l'eau et d'y réduire les rejets, et ce, à un coût minime.

Dans les abattoirs de bétail, les principaux postes où l'eau a été économisée étaient ceux du lavage de l'étamine qui sert à envelopper les carcasses, des lavabos, du lavage des carcasses et des tables de lavage des viscères. Dans les abattoirs de volaille, on est parvenu à économiser l'eau surtout aux postes de lavage des cages, de transport de la plume, des lavabos à cols de cygne et du lavage en retour des tamis rotatifs.

Dans les deux abattoirs de bétail, on a considérablement réduit la charge des effluents, principalement en améliorant la récupération du sang. La DBO_5 a ainsi été réduite de 48 à 56%. Dans les deux abattoirs de volaille, il n'y a pas eu de réduction notable de la charge des effluents.

Toutes les modifications apportées aux méthodes ont été étudiées par Agriculture Canada et les inspecteurs des usines avant leur mise en application. En cours de démonstration, elles ont été évaluées pour que la qualité des produits n'en souffre pas. Le coût maximal de la mise en application d'une modification, après sa démonstration, a été de 7 000 \$ (dispositif de récupération du sang dans l'un des abattoirs de bétail). Le coût moyen des autres modifications a été de 500 \$. Certains changements n'ont rien coûté. Dans tous les abattoirs, les coûts ont pu être recouverts en moins d'un an.

Les particularités des formes de consommation de l'eau et des installations, dans une usine donnée, sont un facteur dont il faut tenir compte lorsqu'il s'agit de déterminer les modifications qui donneront des résultats valables. Des plans bruts de recyclage de l'eau ont aussi été élaborés.

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SUMMARY

The costs to industry for water, energy and pollution control are increasing significantly. The meat and poultry processing sectors are particularly vulnerable to escalating operating costs because they are intensive users of water and energy, and generate considerable quantities of concentrated process effluents. This investigation was initiated jointly by Agriculture Canada and Environment Canada to:

- 1) document existing and potential methods of water and waste conservation applicable to Canadian meat and poultry processing operations; and
- 2) demonstrate practical and economical methods for in-plant control of water use and waste loadings in Canadian meat and poultry processing plants.

Subsequent to visits to Canadian and American meat and poultry processing plants to evaluate existing water and waste management practices, demonstration studies were conducted at two Canadian red meat processing facilities and two Canadian poultry processing facilities to document the feasibility of in-plant control of water use and process effluent waste loadings. These studies confirmed that water use and waste load reductions could be accomplished at minimal cost in Canadian meat and poultry processing operations. In all four plants involved in the investigation, significant reductions in water usage were demonstrated. The savings in annual usage varied from about 10 percent to over 25 percent.

In the red meat processing plants, the major areas of water use reduction involved shroud washing processes, employee handwashers, carcass washers and viscera table washing systems. In the poultry processing plants, major reductions were accomplished in the water use associated with coop washing, feather transport, gooseneck handwashers and rotary screen backwashing.

Considerable reductions in process effluent waste loadings were demonstrated at both red meat packing plants. This was accomplished primarily by improving the blood recovery systems in use at these plants. The process effluent BOD₅ loading was reduced from 48 to 56 percent in these instances. There was no significant decrease in the waste loads at either of the two poultry processing plants.

All process modifications were reviewed by Agriculture Canada and plant inspection staff prior to installation and evaluated during the in-plant studies to ensure that no detrimental effect on product quality resulted.

The maximum cost of any single modification installed as a result of the demonstration studies was \$7 700 for a blood recovery system at one of the red meat packing plants. The average cost of all other modifications was approximately \$500. Several changes were implemented at no cost. The total direct cost of all in-plant modifications was about \$21 000.

At all four plants, the costs of the modifications could be recovered in less than one year. These savings resulted from a combination of reduced water and sewer costs as well as a substantial reduction in the high strength effluent surcharges levied against two of the plants. At one plant, a substantial return-on-investment was associated with the sale of blood recovered through in-plant modifications. The total annual return realized as a result of the modifications at all four plants was more than \$51 000.

The following table summarizes the results of the demonstration studies.

		Plant			
		(poultry) A	(poultry) B	(beef, sows) C	(beef) D
Reduction in					
i)	Annual Water Use				
	(m ³)	97 732	25 272	20 500	28 390
	(%)	26	12	21	9
ii)	Waste Load	Not	Not		
	(kg/d BOD ₅)	Significant	Significant	342	673
	(%)	-	-	48	56
Cost (\$)		5 948	3 260	9 222	2 852
Annual Savings (\$)		16 028	3 529	17 295	14 865

The demonstration studies developed a practical approach to water and waste management programs at meat and poultry packing plants. The site-specific nature of water use patterns and facilities at a particular plant was determined to be an important factor in identifying the modifications that can be successfully implemented.

A number of reuse/recycle schemes which require further study were also identified. These schemes could result in further reductions in water use in meat and poultry processing plants, but require the sanction of Agriculture Canada. It is recommended that further investigations be directed to this area to determine whether these recycle/reuse systems are acceptable.

The results of these demonstration studies indicate that most Canadian meat and poultry processors can accomplish some reduction in water use and/or waste load at minimal cost. The economic return from such programs will depend on the site-specific costs associated with purchasing water and disposing of process effluents.

1 INTRODUCTION

All industrial sectors in Canada have been affected by the increased public awareness of the necessity for protection of the natural environment. Increasingly stringent government regulations and guidelines regarding waste discharges, combined with inflation in the cost of water and wastewater treatment, have had a significant impact on plant operating costs in recent years.

The meat and poultry processing industry is considered a high volume water user. Wastewaters from the industry contain high concentrations of biodegradable organic matter, suspended solids and grease. It was estimated, based on a survey of the Canadian industry (1), that in excess of 16.6 million cubic metres of water was used in red meat processing in 1972 and the resultant effluent load exceeded 18 million kilograms of biochemical oxygen demand (BOD_5). Data for the poultry processing industry for the same year indicates water use in excess of 12.7 million cubic metres, with a resultant effluent loading of more than five million kilograms of BOD_5 . The impact of closer environmental regulation and higher water and wastewater disposal costs can obviously affect the stability of the industry, particularly during periods of higher labour, energy and raw material costs.

Water is used in the meat and poultry processing industry to clean and sanitize equipment and product, in heat transfer operations, and to transport products and waste materials. A basic factor in the use of water in the food industry is the concept of cleanliness and product quality. In this regard, the industry has an enviable record of maintaining sanitary conditions and marketing a wholesome product. However, in many cases, excessive quantities of water are used inefficiently in operations not affecting product quality, particularly in the transport of waste materials.

Numerous articles have been written detailing methods available to control water use and reduce waste loads from the meat and poultry processing industry. Intensive in-plant demonstration studies have been conducted in red meat and poultry processing plants in the United States, with very favourable results in terms of reductions in water use and waste loadings. However, the results of American studies may not always be directly applicable to the Canadian situation due to such factors as differences in raw materials and products, size and location of processing plants, nature of processing equipment and procedures and, perhaps most importantly, differences in the respective Department of Agriculture inspection techniques and regulatory requirements.

1.1 Scope of the Study

Based on the favourable results reported from in-plant demonstration studies conducted in the United States and a concern regarding the applicability of these results to the Canadian industry, Stanley Associates Engineering Ltd. of Calgary, Alberta and Dearborn Environmental Consulting Services of Mississauga, Ontario were retained jointly by Agriculture Canada and Environment Canada to conduct a comprehensive study of water and waste management practices relevant to meat and poultry processing facilities in Canada.

The primary objective of the program was to demonstrate, in four Canadian red meat and poultry processing plants, the effectiveness of water and waste management programs. The scope of the demonstration studies included:

- characterization of existing water use practices and process effluent loadings,
- identification of potential areas for water conservation and waste management modifications,
- incorporation of minor in-plant modifications to effect water use or waste load reductions,
- evaluation of water use and waste load reductions resulting from the implementation of the in-plant modifications,
- documentation of any possible effect on product quality resulting from in-plant changes,
- economic analysis of costs and savings related to the water and waste management programs, and
- identification and recommendation of major areas where water use and waste loadings reductions could be potentially realized.

In addition to the specific objectives of the demonstration studies, the overall program included the following secondary objectives:

- to prepare a detailed literature and industry review of existing and potential methods of water and waste conservation applicable to Canadian meat and poultry processing operations;
- to assess the possible impacts of water and waste conservation practices and water use schemes on product quality, product utilization, and byproduct recovery; and
- to estimate the potential economic and environmental benefits of water and waste management programs on the Canadian meat and poultry processing industry.

1.2 Report Organization

The report provides an account of the water and waste management demonstration studies conducted at four Canadian meat and poultry processing plants during the winter of 1978/1979 and spring of 1979, and a number of appendices of background information relevant to the investigation. The information is primarily intended for the processing plant owner, operator or engineer, and it is assumed that the reader is conversant with industry practices.

Section 2 of the report provides a review of two United States government (Environmental Protection Agency) in-plant studies which have been used extensively as the basis for most subsequent in-plant water and waste management programs (2, 3). More detailed literature reviews documenting the means available within each unit process of meat and poultry processing to control water use are provided in Appendix A. These reviews include discussions of new equipment developments which may affect traditional water use patterns in the industry. The material presented in the Appendices will be particularly useful to plant management personnel embarking on a similar water and waste management program.

The procedures used during the demonstration studies are outlined in general in Section 3. The methods used to collect baseline data characterizing the water use patterns and waste loads at each plant, the procedures used to implement the various in-plant changes, including the involvement of plant and inspection staff in identifying and executing the modifications, and the approaches used for final data collection and handling are described.

Each demonstration plant is discussed separately in Section 4. Process descriptions, pre-study conditions, modifications and resultant impacts on water use and waste loads are documented for each plant. The economic implications of each in-plant modification are also discussed.

Finally, the results of the demonstration studies and technology review are summarized in Section 5. An attempt has been made to extrapolate, in a general fashion, the results of these four in-plant studies to the Canadian meat and poultry industry as a whole to provide an indication of the economics of water and waste management programs.

Appendix C provides a tabulation of some typical Canadian water, sewer and surcharge rates. Equipment used during this study, and suppliers of new processing equipment which may effect water and waste conservation in processing plants are provided in Appendix B.

2 TECHNICAL BACKGROUND

Data collected as a result of an industry-wide survey of Canadian red meat processors in 1972 indicated that water usage in the industry averaged approximately 15 L/kg live weight killed (LWK) in plants slaughtering more than 2.5 million kilograms live weight per year (1). However, of considerably more significance was the water usage, on a production basis, which varied over a 25-fold range (approximately 2.5 to 60 L/kg LWK). In the poultry processing industry, from the same data source, average water usage was approximately 35 L/bird, but production-based usage varied over a five-fold range (approximately 13 to 69 L/bird).

Obviously, the amount of water used depends on the type of meat (beef, hog, sow, etc.) or poultry (broiler, turkey, fowl, etc.) handled in the particular plant as well as such factors as plant size, production rate, degree of complexity and type of equipment used. However, equally obvious is the fact that some plants are using water more efficiently than others. Plants producing similar products from similar raw materials using similar processes exhibit vastly different water use patterns and waste load characteristics. Very often, plant personnel do not even know the amount of water being used.

In many cases, the differences between efficient and inefficient use of water relates to the general plant attitude regarding water and waste management practices. In such cases, the modifications required to effect substantial water use reductions are straightforward and the costs are minimal.

2.1 Incentives for Water and Waste Management Programs

The major cost factor for the meat and poultry processor is the cost of livestock. Other factors which strongly influence annual operating costs include the cost of labour, plant and facilities, and transportation costs. Profitability is ultimately determined by the market value of the final product. In an existing establishment, the processor has limited control over these factors.

In terms of the actual percentage contribution to total operating cost, the cost of purchasing water and disposing of wastewater may be relatively small. However, annual water and wastewater costs can be controlled by the processor by minimizing the process water requirements. Furthermore, the cost of water and wastewater disposal is escalating, contributing to the overall inflation in plant operating costs. Perhaps the most important factor contributing to the increased water and sewage costs has been the

implementation, in many municipalities, of industrial waste bylaws regulating discharges to municipal sewer systems.

Typical water and sewer charges in Canada range from \$0.15 to \$0.30/m³. This represents less than \$0.004/kg LWK for a meat packer, or \$0.008/bird for a poultry processor operating at the average water consumption rate. However, for high volume water users, water and sewer costs could represent \$0.02/kg or \$0.016/bird at a unit cost of \$0.22/m³. Combined water and sewer costs of \$0.33/m³ are becoming common in large municipalities.

Of further concern to processors is the implementation of sewer surcharges as a result of industrial waste bylaws. These surcharges are assessed on industry for discharging high-strength wastes in excess of those considered to be covered by the basic sewer charge. The concept behind these over-strength charges is stated in the recently enacted United States Public Law 95-217:

"Operation, maintenance and replacement (O, M & R) costs for waste treatment must be distributed to users (or user classes) in proportion to the total loading of each user (or user class)."

In Canada, many municipalities have already enacted a surcharge system. Costs for discharging effluents containing BOD₅, suspended solids, and oil and grease concentrations in excess of the bylaw limits are as high as \$0.014/kg. (Further details regarding surcharge calculations and typical Canadian rates are presented in Appendix C). Furthermore, in the United States, some municipal bylaws include limits on discharges of total Kjeldahl nitrogen (TKN) (4). As proteinaceous material lost to the sewer during meat processing, and ammonia discharges resulting from poultry defeathering operations contribute to high TKN levels in meat and poultry processing effluents, this will be of considerable importance to the industry if the American example is followed in Canada. The overall result of the practice of sewer surcharging will be higher operating costs to the processor.

It has been demonstrated that reductions in water use are often accompanied by significant reductions in waste load. Control of the contact between water and various waste materials will minimize solubilization of blood and other proteinaceous matter which contribute to effluent BOD₅. Thus, in-plant control of water use can also result in reductions of effluent surcharges. It is evident that water and waste management practices could result in improved profitability for the meat and poultry processing industry as a result of direct reductions in operating costs. Studies reported in the

following section of this report and documented in the Appendices have shown that these programs can be simple and inexpensive in most cases.

2.2 Review of American Water and Waste Management Studies

The United States Environmental Protection Agency (U.S. EPA) has sponsored two intensive water and waste management programs, one in a hog slaughtering operation (2) and one in a poultry processing operation (3). These studies have become the basis for much of the in-plant work which has been initiated by the industry. The overall results of these two studies are summarized in the following sections. More detailed information regarding the individual in-plant modifications is presented in Appendix A.

2.2.1 The Oscar Mayer Study. In-plant studies were carried out in three Oscar Mayer and Co. plants located at Madison, Wisconsin; Beardstown, Illinois; and Davenport, Iowa between 1974 and 1976. The majority of the effort was concentrated on the hog slaughtering operation at the Madison plant. This plant was built in 1917 and progressively expanded to a capacity of 1 000 hogs per hour at the time of the study.

Prior to the study program, water use at the hog slaughtering plant was approximately $2\,000\text{ m}^3/\text{d}$ (3 L/kg LWK), with a resultant BOD_5 load of $2\,800\text{ kg/d}$ ($4.26\text{ kg}/1\,000\text{ kg LWK}$). The hog slaughtering line is typical of most large operations. Principal water users in the process were identified as the dehairing machine, the stomach washer and the hasher-washer. These areas also contributed the major fraction of the BOD_5 load.

The major changes in the process were:

- a) Blood collection and dry cleaning of the bleeding area were improved, resulting in an increase in blood recovery of approximately 11.3 kg/d and a BOD_5 reduction of 2.3 kg/d .
- b) Improved spray nozzles were installed in the rail polisher, carcass shower, head washers, chitterling washers and viscera handling areas.
- c) Dry cleanup was initiated in all areas and screens were installed on drains to prevent gross solids from entering the sewer system.
- d) The knife blades were removed from the hasher-washer and the unit operated simply as a dewatering device. Intact intestines were sent to inedible rendering.
- e) A Chad neck washer was installed to eliminate the manual neck washing operation.

The final result of the in-plant program was the following reductions in water usage and effluent loading:

- Flow was reduced 41% to $1\,200\text{ m}^3/\text{d}$ ($1.81\text{ m}^3/\text{kg LWK}$).

- BOD₅ was reduced 63% to 1 000 kg/d (1.5 kg/1 000 kg LWK).
- Suspended solids were reduced 63% to 1 000 kg/d (1.5 kg/1 000/kg LWK).

Many of the modifications involved no significant cost. Even the most expensive modification was estimated to pay for itself in less than two years. The total present value of savings due to the modifications over five years at 10 percent interest was estimated at more than half a million dollars in this particular case. A summary of the costs and savings resulting from each in-plant modification is given in Table 1.

2.2.2 The Gold Kist Study. The Gold Kist Inc. plant in Durham, North Carolina was the site of a water and waste management demonstration study for the poultry processing industry between 1969 and 1972. The Gold Kist plant processed 70 000 broilers per day at the time of the study, using approximately 44 L/bird. Process effluent waste load from the operation was 1 800 kg/d BOD₅.

The major modifications made during the course of the study were:

- improved blood recovery,
- reuse of chiller overflow in the scalding,
- installation of efficient spray nozzles in whole bird and final bird washers,
- use of flow-reducing nozzles and/or demand valves on goosenecks,
- installation of timer-controlled solenoid valves and pressure regulators in the sidepan wash system, and
- implementation of dry cleanup procedures.

The reductions in water use from these modifications are summarized in Table 2. The overall results of the program were reductions of 32 percent in water use and 66 percent in effluent BOD₅ loading. The impact of the water and waste management program on the plant operating costs is summarized in Table 3.

2.3 Constraints on Water and Waste Management Programs

Despite the apparent overwhelming success of these two American case histories, there are constraints on such water and waste management programs which should be considered. Both studies were relatively long-term and involved substantial outlays of capital, in some instances, for major new equipment such as electric stunners, flotation cells, and head and neck washers. Obviously, the degree of success which can be anticipated in any such program will depend to a large extent on the magnitude of the changes that are incorporated.

TABLE 1 OSCAR MAYER STUDY, COST AND SAVINGS RESULTING FROM IN-PLANT CHANGES

Problem Area*	Cost of Change	Annual Savings	Notes
Bleed trough	\$ 0	\$ 40	-----
Bleed trough cleanup	\$ 3	\$ 40	-----
Bleed conveyor sprays	\$ 0	\$ 260	-----
Hair chute, Davenport plant	\$ 22 000	\$ 19 406	-----
Rail polisher shut off, Beardstown plant	\$ 255	\$ 624	-----
Final carcass shower, Madison plant	\$ 184	\$ 853	-----
Final carcass shower, Beardstown plant	\$ 88	\$ 2 080	-----
Eyelids on floor	\$ 86	-----	Increased byproduct recovery value unknown
Brisket splitting	\$ 2 377	\$ 4 078	-----
Bone dust - carcass splitting			
Viscera pan wash sprays			
Viscera pan wash solenoid valves	\$ 1 285	\$ 2 907	-----
Hasher-washer blade removal	\$ 275	\$ 42 697 \$ 96 244	Pollution reduction Increased byproduct recovery
Head washer	\$ 0	\$ 831	-----
Neck washer	\$ 17 000	\$ 30 000 \$ 4 858	Reduced labour Reduced pollution and water consumption
Chitterling washer, Beardstown plant	\$ 78	\$ 5 070	-----
TOTAL	\$ 43 631	\$ 209 988	

* Madison, Wisconsin, plant except where noted.

TABLE 2 WATER REDUCTION ACHIEVED DURING GOLD KIST STUDY

Area of Plant	Activity	Reduction in fresh water use (U.S. gal/min)	
		From	To
Evisceration	Use of improved nozzles:		
	Final bird washers	50	30
	Hand washers	285	100
	Cycling of sidepan wash	90	30
	Rearrangement of giblet handling	360	320
Scalding and Defeathering	Use of improved nozzles in whole-bird washers	45	30
	New design of feather flume for reuse of offal-flume waters	94	0
	Use of chiller water in scalders to replace fresh water	40	0
Cleanup	New high-pressure cleaning system with foam	112 000*	46 000*

* Cleanup data given in U.S. gallons per day.

TABLE 3 ECONOMIC EFFECT OF WATER AND WASTE MANAGEMENT PROGRAM AT GOLD KIST

Item	Before Study	After Study	Improvement
Water cost*	\$ 3 238	\$2 199	\$1 039
Sewer cost*	3 546	2 408	1 138
Surcharge*	3 390	223	3 167
Total*	\$10 164	\$4 830	\$5 344
Litres per bird	43.5	29.6	13.9
BOD ₅ in effluent	560 mg/L	282 mg/L	298 mg/L

* Average monthly costs associated with each of these services.

The impact of a water and waste management program in a specific plant will depend on existing conditions. Some plants already exhibit good water use practices and substantially more complex modifications may be necessary to effect the same reductions in water and waste loads as would be possible in a poorly-managed plant. Thus, extrapolation of results from any one plant to another is not necessarily possible.

There are significant differences in processing and inspection practices between the United States and Canada which may affect the applicability of the results of American studies to the Canadian situation. Although Canadian and American meat and poultry processing establishments are similarly located (primarily in urban areas), employ the same type of worker, and express the same management attitude towards conservation, American plants tend to be larger than Canadian plants. In addition, American plants are generally more automated because new equipment is generally proven in the United States before the technology is exported to Canada.

An important difference between the Canadian and American industries relates to the type of regulations applied by the respective Departments of Agriculture (USDA and Agriculture Canada). In both cases, the goal of federal inspection is to ensure that meat products are clean, free of disease or adulteration, and fit for human consumption. However, in the United States, the USDA places quantitative limits on water use in some processes such as scalders, and giblet and carcass chillers. In Canada, Agriculture Canada regulations are more qualitative and responsibility for ensuring adequate water usage is placed on the inspector-in-charge at the plant. Thus, requirements can change depending on specific conditions at the particular plant.

Traditionally, inspection personnel have emphasized the importance of large volumes of water in maintaining sanitary conditions and ensuring product quality. Recently, in both Canada and the United States, the importance of efficient use of water has been recognized as more relevant to sanitation than volume of water. Inspection personnel are receptive to modifications relating to more efficient water use, with the provision that plant sanitation and product quality are not adversely affected.

3 METHODOLOGY OF DEMONSTRATION STUDIES

The primary objective of the study program was to demonstrate the effect of minor in-plant modifications on water usage and waste loadings at four typical Canadian red meat and poultry processing operations. The in-plant programs involved four separate but interrelated phases:

- a) plant selection,
- b) baseline plant monitoring,
- c) implementation of modifications, and
- d) final plant monitoring.

The demonstration studies involved approximately six months of in-plant work at each of the selected facilities.

In this section, the procedures used to define water use practices and determine areas of potential water conservation or waste management are discussed. The study involved four plants, located in two provinces, which produce a wide variety of products. The techniques used at each plant varied in some instances; specific details of the sampling, flow measurement and data handling are discussed in Section 4 wherever this information is considered relevant to the results of the program.

3.1 Plant Selection

The basic criteria for plant selection were that the particular plants should be relatively compact and utilize a level of technology considered typical of the Canadian industry. The size criterion was included to ensure that an inordinate amount of time would not be required to locate raw water piping and drains, and isolate unit processes in a large, complex packinghouse. Fourteen plants were selected for preliminary evaluation as possible test sites. These included two poultry and four red meat processors in Alberta, and three poultry and five red meat processors in Ontario.

The fourteen establishments were visited to assess existing water use practices, management attitude toward the goals of the study, and the potential for in-plant modifications within the existing facilities. Based on these plant visits, the following four plants were selected for the demonstration studies.

- 1) Pinecrest Foods Ltd.,
Calgary, Alberta

- 2) Checkerboard Foods Ltd.,
Aurora, Ontario
- 3) Prime Packers Ltd.,
Toronto, Ontario
- 4) Dvorkin Meat Packers Ltd.,
Calgary, Alberta

All of these plants would be categorized as "typical" according to the classification outlined in the "Inventory of the Meat and Poultry Products Industry in Canada" (1), with the exception of Prime Packers Ltd. This particular plant would probably be classified as "old" as there is no recovery of sow blood. However, the plant also uses several "advanced" processes such as dry dumping of paunches, dry edible rendering and primary material (grease and solids) recovery.

3.2 Baseline Plant Monitoring

To provide a basis for evaluation of the effect of the in-plant changes on water use and effluent loading, approximately two months were spent in each plant identifying existing water use practices and process effluent waste loads. This intensive monitoring period also allowed identification of major water use areas and areas where possible modifications could be implemented.

3.2.1 Water Use. Water use measurements were designed to provide information on a daily basis as well as separate measurement of the amounts of water used during production, and cleanup, and in secondary processes such as refrigeration, heating and ice-making.

All four demonstration plants purchased water from a municipality and consumption was measured by water meters. These meter readings were used to determine daily water use during the in-plant programs. Meter readings were taken daily at the start of the production shift (approximately 1500 to 1600 hours) and, on less frequent occasions, at the end of the cleanup shift (approximately 2400 hours). Thus, water usage during each shift could be defined.

Daily production data were also compiled from plant records. Depending on the particular method used to record production at each plant, the number of animals received, and either live weight or dressed weight data were used to derive production-based water usage.

In addition to plant water use data, water usage in each unit process was defined. Water meters were installed in various freshwater lines throughout the plants.

In most cases, cumulative use meters were used. However, in some areas where such meters could not be installed, instantaneous in-line units were used. Where it was not feasible to install meters in freshwater lines serving a unit process, flow rates were measured by means of a calibrated container and a stop watch.

Large intermittent flows, particularly those associated with filling large tanks such as scalders and chillers, also contributed to the total plant water usage. In such cases, the tank volumes were estimated based on tank dimensions, or obtained from the equipment supplier, and the water used in initial filling included in the unit process water use.

The unit process water data was used to complete a water balance around the plant. For a one-hour period during the production shift, total plant water use from the main city meters and the water used in each unit process were recorded. This data, provided verification that all major water usages in the plant had been taken into account. The major water use areas of each plant could also be identified.

At the Checkerboard Foods poultry plant, total process effluent flow rate was measured through a Parshall flume. The continuous flow record provided further information relating to the daily water use patterns, and confirmed the water use readings obtained from the city meters. Similar data were not available from the other three plants.

The individual streams measured, and the procedures used for each stream are summarized in Tables 4, 5, 6 and 7 for each plant.

3.2.2 Waste Loadings. The emphasis during the monitoring program was placed on defining the total process effluent loads for the four plants. Automatic samplers were used to collect 24 hourly samples from the total plant effluent. At Checkerboard, samples were collected after in-plant grease recovery but prior to the biological treatment system. At the other three plants, the effluent samples represented the discharge to the municipal sewer after primary materials recovery (by dissolved air flotation at Dvorkin and Pinecrest; by grease traps at Prime Packers). However, additional samples were also taken before primary materials recovery at the latter three plants, and after biological treatment at Checkerboard to provide an indication of the treatment efficiency attained in these systems.

The hourly samples collected by the automatic sampling equipment were composited to produce either a single daily sample representative of the total effluent load, or two samples representative of the load during the production shift and the cleanup shift separately.

TABLE 4 FLOW MONITORING LOCATIONS AND TECHNIQUES, PINECREST FOODS LTD.

Area Monitored	Description	Measurement Technique
Total Plant	City Water Main	2 Neptune Trident Compound meters
Receiving Area		
a) Coop Trailer Wash	Spray Nozzles	Estimate based on design specifications and utilization
b) Cleanup	Hoses	Bucket and stopwatch and Neptune Trident meter
c) Foot Recovery		
- Spray	Spray Nozzles	Bucket and stopwatch
- Feather float	Hose	Bucket and stopwatch
Stunner	Makeup Water	Bucket and stopwatch
New York Room		
a) Scalding	Initial Fill	Manufacturer's specifications
	Makeup Water	Neptune Trident meter
	Overflow	Bucket and stopwatch
	Steam	Estimate as a proportion of boiler usage
b) Defeathering Machines	Drilled pipe for lubrication and feather flushing	Neptune Trident meter
c) Potable Water to Feather Flowaway	Hose	Neptune Trident meter and bucket and stopwatch
d) First Bird Wash	Domestic Showerheads	Neptune Trident meter
e) Cleanup	Hoses	Neptune Trident meter and bucket and stopwatch
Rehang Belt	Drilled Pipe Spray	Included in second bird wash meter
Second Bird Wash	Domestic Showerheads	Neptune Trident meter

TABLE 4 (Continued)

Area Monitored	Description	Measurement Technique
Evisceration Area		
a) Vent Guns	Automatic Wash	Bucket and stopwatch and utilization rates
b) Work and Inspection Stations	Goosenecks	Neptune Trident meters and bucket and stopwatch
c) Sidepan Wash	Drilled Pipe	Neptune Trident meters
d) Sterilizers	Makeup Water	Neptune Trident meter
e) Giblet Transportation	Flumes	Neptune Trident meter
f) Gizzard Split and Flush	Automatic Equipment	Neptune Trident meter
g) Gizzard Peel	Domestic Showerheads	Neptune Trident meter
h) Cleanup	Hoses	Neptune Trident meter and bucket and stopwatch
Chilling		
a) Prechill Tank	Initial Fill	Manufacturer's specifications
	Make up Water	Bucket and stopwatch
	Overflow	Bucket and stopwatch
b) Chill Tank	Initial Fill	Manufacturer's specifications
	Make up Water	Bucket and stopwatch (baseline) Neptune Trident meter (post-modification)
c) Giblet Chilling	Ice	Included in ice making measurements
Ice Making	Manufactured Ice	Estimate on capacity
	Overflow	Bucket and stopwatch
Thawing	Hoses	Bucket and stopwatch
Compressors	Cooling Water	Bucket and stopwatch
Vacuum Pumps	Seal Water	Bucket and stopwatch
Rotary Screens	Backwash	Neptune Trident meter

TABLE 5 FLOW MONITORING LOCATIONS AND TECHNIQUES, CHECKERBOARD FOODS LTD.

Area Monitored	Description	Measurement Technique
Total Plant	City water main	Neptune Trident Compound Meter
Receiving Area		
a) Truck Wash	Hose	Neptune Trident meter
b) Cleanup and Drinking Water	Hose and Tap	Neptune Trident meter
c) Coop Wash	Makeup water	Bucket and stopwatch
Killing		
a) Stunner	Makeup water	Bucket and stopwatch
b) Automatic Killer	Sprays on Guide Bar	Bucket and stopwatch
Scalding	Initial Fill and Cleanup	Estimated tank volume
	Makeup and Conveyor Lubrication Sprays	Bucket and Stopwatch
Pickers (2)	Internal lubrication and Feather Removal	Hedland in-line flowmeters (2)
Whole Bird Washer	Domestic Showerheads	Bucket and stopwatch
Hock Cutter	Lubricating Spray Nozzle	Bucket and stopwatch
Rehang Belt	Conveyor spray wash	Bucket and stopwatch
Eviscerating Room		
a) Automatic Equipment	Spray washes	Bucket and stopwatch
b) Inspection Stations	Goosenecks (4)	Bucket and stopwatch
c) Gizzard Splitter	High-Pressure System	Neptune Trident meter
d) Gizzard Washer	High-Pressure System	Neptune Trident meter
e) Final Bird Washer	Showerheads	Bucket and stopwatch
Prechill Tank	Initial Fill and Makeup	Neptune Trident meter
Chill Tank	Initial Fill and Makeup	Neptune Trident meter
Giblet Chillers	Makeup Water	Bucket and stopwatch
Thawing	Thawing water	Bucket and stopwatch
Packing Machines	Cooling Water	Bucket and stopwatch
Freezer	Deicing Water	Bucket and stopwatch
Process Effluent	Biological Treatment Plant	Parshall flume and Kent Cambridge 24-hour chart recorder with totalizer

TABLE 6 FLOW MONITORING LOCATIONS AND TECHNIQUES PRIME PACKERS LTD.

Area Monitored	Description	Measurement Technique
Total Plant	City water main	Rockwell meter
Blood Bucket Wash	2 1.9-cm lines	Hedland in-line rotameter
Bleed Station (Beef)	7.5-cm Hand-held Shower	Bucket and stopwatch
Bleed Station (Sow)	1.3-cm Hose	Bucket and stopwatch
Sow Scalding	5-cm Line	Measured volume of tank
Main Sow Shower	15-cm Domestic Showerhead	Bucket and stopwatch
Main Sow Shower (after improvement)	3-Nozzle Header with Pressure Regulator	Manufacturer's specification tables Bucket and stopwatch
Sow Head Shower	2 2.5-cm Domestic Showerheads	Bucket and stopwatch
Tongue Wash	1.3-cm line with valve	Bucket and stopwatch
Carcass Wash	1.3-cm line with Trigger Nozzle	Bucket and stopwatch
Cleanup Hoses	1.9-cm Hot Water Hoses	Bucket and stopwatch plus Hedland in-line rotameter
Shroud Wash	2.5-cm line	Sweep check on main Rockwell meter at night
Sterilizers	Overflow	Bucket and stopwatch
Evisceration Table Spray Wash	3 1.9-cm lines	Sweep check on main Rockwell meter at night
Background (boilers, cooling towers, washroom, etc.)		Sweep check on main Rockwell meter at night and during lunch

TABLE 7 FLOW MONITORING LOCATIONS AND TECHNIQUES,
DVORKIN MEAT PACKERS LTD.

Area Monitored	Description	Measurement Technique
Total Plant	City water main	Neptune Trident compound meter
Wash Sinks		
a) Uncontrolled	Goosenecks	Neptune Trident meters
b) With Showerhead		
c) With Foot Control		
Wet Paunch Dump	Drilled pipes to flush paunch and transport contents	Neptune Trident meter
Viscera Table Wash	Drilled pipe and spray nozzles	Neptune Trident meter
Carcass Wash	Oscillating high-pressure spray nozzles	Estimate based on manufacturer's specifications

In addition to these composite process effluent samples, selected streams within the plants were sampled to provide some indication of the effluent loadings resulting from various unit processes. These samples were generally manually collected and composited over a short period (approximately four hours). Because the discharges from individual unit processes usually could not be segregated from the total plant effluent, only minimal sampling of this kind was done.

The basic analyses conducted on these effluent samples were BOD₅, suspended solids, oil and grease, and occasionally total Kjeldahl nitrogen (TKN). All determinations were conducted according to the procedures outlined in Standard Methods (6).

3.2.3 General Observations. In addition to the sampling and quantification of flows, considerable time was spent during the collection of baseline data in general observation of plant water use practices. Cleanup practices and the requirements for maintenance in various areas of the plants were noted so that modifications could be implemented where necessary. Large intermittent usages of water, which were difficult to locate and quantify based on meter readings, were also identified.

3.3 Implementation of Modifications

At the conclusion of baseline data collection, a number of feasible water conservation and waste management modifications were developed for each plant. Possible modifications were identified from published information regarding changes which had been successfully implemented elsewhere, site visits to plants which demonstrated exemplary water use practices, information from equipment suppliers, and ideas solicited from plant personnel and inspection staff.

Formal proposals regarding each change were developed and presented to the scientific authorities representing Environment Canada and Agriculture Canada. Subsequent to any necessary minor changes to these proposals, the modifications were discussed in detail with the veterinarian-in-charge at each plant. Any possible effects on plant sanitation or product quality were discussed in detail. At this time, the proposed modifications were presented to plant management to ensure that plant production would not be adversely affected by any of the changes. In addition, plant supervisory personnel were included in these final approval meetings. The overall goals of the program were discussed and the cooperation of all production personnel was solicited so that water use throughout the plant would be closely monitored and controlled.

Modifications involving equipment purchase were discussed with operations and maintenance personnel to ensure that any equipment installed would be compatible with equipment in the plant. Most installations were simple and straightforward and could be done by plant or study personnel.

The majority of the modifications were made during evening or night shifts or on weekends to ensure that there was no interference with production. Where possible, the original equipment was left in place with bypasses in case any problems developed with the modification.

In general, water use monitoring was continued during implementation of the in-plant modifications. The modifications required approximately two months to complete, depending on the time available from plant personnel, the plant production schedule and equipment availability.

3.4 Post-Modification Plant Monitoring

The procedures used in assessing the water usage and waste loading after in-plant modifications were similar to those used for the collection of baseline data and described in Section 3.2. However, more emphasis was placed on measuring flows in the unit processes where modifications were made.

As an important aspect of the assessment of the in-plant changes was acceptability to inspection staff and plant personnel, continuous feedback from these people was solicited. In some cases, minor changes to an installation had to be made over several weeks before it was acceptable to all concerned. As the demonstration studies resulted in the installation of new equipment which was unfamiliar to production and inspection staff, this equipment received very close scrutiny for a significant length of time before it was finally deemed acceptable.

3.5 Data Handling

The baseline and post-modification water use data were computed on a "production" and "non-production" day basis, as well as an equivalent annual basis. Non-production days were considered, in general, to be holidays and weekdays. The equivalent annual usage was calculated as the sum of the average production day usage times 245 production days per year, and the average non-production day usage times 120 non-production days per year.

The "production-based" usage was defined as water use per unit of production. It was calculated for the total water use including production and non-production days (total production-based water use). Additionally, it was calculated for production days only (production day production-based water use). The former water use figure is slightly higher than the latter as it includes all water used in the plant.

Waste loadings were, in general, calculated based on the average water use for each individual shift during the day and the average strength of composite samples of the effluent stream during that particular shift. The waste loadings from each shift were then summed to derive the total daily waste loading. These loadings were computed only for production days.

The specific methods used to calculate water use and waste load at each plant varied depending on the type of livestock being handled during the monitoring period, the production schedule, and the basic mode of water use (constant or intermittent). More detailed discussion of the calculation methods is provided in Section 4.

The ultimate goal of the demonstration program was to document the economic implications of water and waste management programs in red meat and poultry processing operations. Thus, the final result at each plant would be a comparison of the monies saved as a result of the in-plant changes and the actual cost (capital and labour) of these changes.

For the purposes of these calculations, water and sewer costs and overstrength surcharges applicable to the particular plant were applied. Appendix C provides comparable charges in other Canadian municipalities to allow extrapolation of these results to other areas. In addition to the economic comparisons for total plant operation, the economics of each individual modification were also evaluated. Equipment costs used in these calculations were those actually charged (1979 \$) by the suppliers. Labour costs were generally based on installation by plant personnel at an average hourly rate of \$10.00. Where outside contractors were required for a specific installation, the actual labour rates charged were applied to the cost of that particular modification. No costs were included for maintenance or depreciation on the equipment as the majority of the modifications involved low maintenance items such as tanks, valves, piping, spray nozzles and pumps. Annual costs were based on a 245-day production year.

4 RESULTS OF DEMONSTRATION STUDIES

4.1 Pinecrest Foods Ltd.

4.1.1 Plant Description. Pinecrest Foods Ltd. is a major slaughterer and packer of poultry in Calgary, Alberta. The plant facility, located in an area of intensive urban land use, is 25 years old. Although broiler chickens constitute the bulk of its product, any particular day's production may involve several different types of birds, including roasting chickens, cornish hens, fowl, and turkeys. In addition, the plant occasionally packs and distributes poultry imported from other plants to nearby markets.

The 1978 total production amounted to 6.7 million birds at an average of 1.86 kg live weight killed (LWK). As is common throughout the industry, Pinecrest's production fluctuates seasonally, and may vary considerably from week to week, or even day to day. At full production, Pinecrest operates one kill line and two evisceration lines, employing about 250 workers who can slaughter, dress, and pack more than 40 000 birds per day. Occasionally, at low production, the plant runs only one evisceration line, reducing its kill capacity by 50 percent, and requiring about 150 workers. During most of the study period, the plant ran one and a half or two lines.

The primary areas in the plant of interest to this study were the receiving area, the bleeding area, the defeathering room and the evisceration area.

Floor trenches collect most of the wastewater and transport it to screening. One trench gathers wastewater mostly from the defeathering room, and serves primarily as a feather flowaway. The other main trench collects primarily from the evisceration operations.

Figure 1 shows the layout of the Pinecrest Foods plant. Slight variations in the illustrated operations occur at lower levels of production and when birds other than broiler chickens are processed. A brief overview of the process flow is provided here for reference during later discussions.

Receiving area. The birds are held in trucks with built-in cages. Maximum truckload capacity is 6160 birds. Workers unload the birds from the trucks and suspend them directly on moving shackles.

Killing and bleeding. The heads of the birds pass through a stunner of electrically-charged water. Next, an automatic killer slits the back of the neck. A manual backup is provided. The birds are bled in a concrete tunnel for between about 90 and 120 seconds, depending

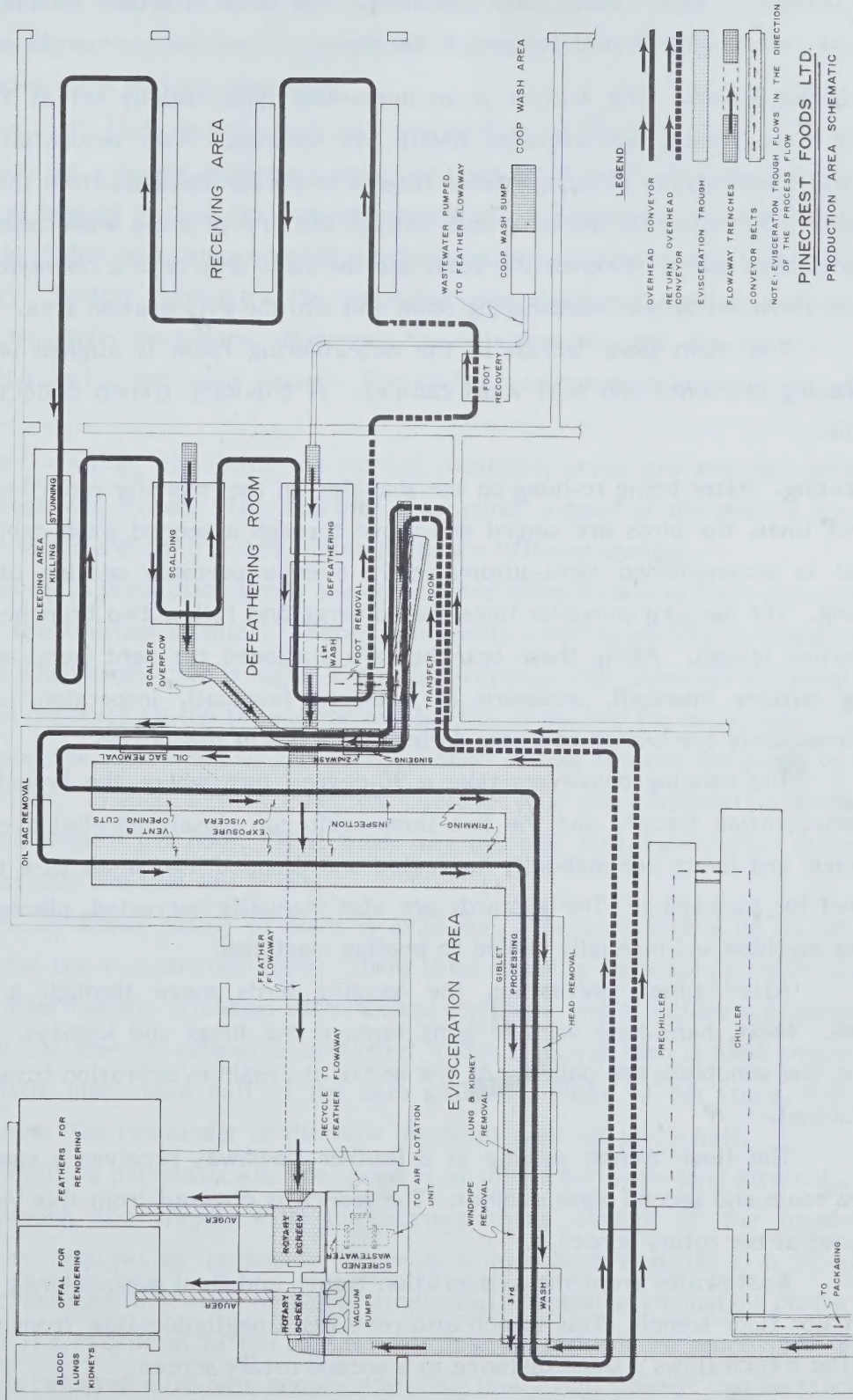


FIGURE 1 PINECREST FOODS LTD. PRODUCTION AREA SCHEMATIC

on the number of evisceration lines operating. The blood is totally contained within the tunnel, to be vacuumed out at the end of the day.

Defeathering Room. The scalding is an immersion type, usually set at 59°C to 60°C. Scalding time varies, but averages about 100 seconds. Two sequential defeathering machines, which utilize rotating rubber fingers to abrade feathers from the birds, follow the scalding. Subsequently the birds pass through the first of three wash cabinets. Then an automatic hock cutter removes the feet, and the birds drop onto a conveyor table, which transfers them out of the defeathering room and into the evisceration area.

The main floor trench in the defeathering room is aligned underneath the defeathering machines and first wash cabinet. A tributary trench collects the scalding overflow.

Eviscerating. After being re-hung on the shackles (in the "transfer room") on two parallel conveyor lines, the birds are singed and move through a second wash cabinet. Oil sac removal is accomplished semi-automatically over a portable section of evisceration troughing. The hanging conveyor lines then diverge and follow two branches of the main evisceration trough. Along these branches are stationed the vent (semi-automatic) and opening cutters (manual), exposure of eviscera (manual), inspection, and trimming operations. Only one branch operates during low levels of production.

The hanging conveyors take a 90-degree turn where the branches enter the main evisceration trough, and the two lines again run closely parallel over one trough. The hearts and livers are manually harvested and dropped into small flow troughs, to be collected for packaging. The gizzards are also manually harvested, placed in a gizzard splitting machine and manually peeled on peeling machines.

After giblet harvesting, the hanging birds move through a head pulling machine. Next, hand-held vacuum guns remove the lungs and kidneys. Before final washing, the windpipes are pulled. At the end of the main evisceration trough is the third wash cabinet.

The floor trench serving as a feather flowaway receives a stream from the transfer room and second wash cabinet. The trench is covered from this vicinity until it resurfaces at the rotary screen.

Wastewater from the evisceration trough and final wash cabinet flows into the other major floor trench. This trench also receives a negligible flow from the packaging area. The trench flows a short distance to a second rotary screen.

Following the final wash the carcasses travel a short distance to drain, go through a house inspection, and are removed from the shackles to be placed on a conveyor belt which carries them into the prechiller.

Pinecrest's chillers are immersion spin chillers. When the study began, the two chillers were similar, a minor difference being that the main chiller was longer. Ice was added to both as needed to maintain low temperatures. About two months into the study period, the main chiller was replaced with a refrigeration jacketed model, larger than the original chiller. Shortly thereafter the prechiller was shortened because such a large prechiller was no longer necessary. However, the refrigeration unit for the new chiller was not installed during the study period. The chiller was operated as previously, by the addition of ice.

After chilling, the birds are sorted, weighed, some are cut up, packaged, graded, and sometimes frozen. This "further processing" aspect of the plant's operation consumes little water and contributes minimally to the effluent loading.

Pinecrest's production levels are determined more by supply from growers than by demand for the finished product. There is no problem selling poultry to retail outlets and restaurants when production is high. The only limitation that prevents the plant from operating at full capacity all the time is the availability of poultry for slaughter.

During the first week of this study, a short supply limited the plant to a low level of production. In such a case, Pinecrest operates only one eviscerating line with a capacity of 3000 broilers per hour. That week was the only sustained period during the entire study that only one line was in use.

When an ample supply of birds is available, Pinecrest speeds up its kill line. The kill line feeds two evisceration lines. Then, total capacity increases to 6000 broilers per hour. An intermediate situation often exists when one and a half eviscerating lines run, and the kill line speed is gauged accordingly. Plant capacity then is 4400 broilers per hour. For a little more than half of the data gathering phase of the study, Pinecrest operated two lines. The remainder of the time the plant used one and a half.

Typically, a particular kill line speed is sustained for week-long intervals. This is because changing the speed, with the accompanying change in the number of eviscerating lines, requires an increase or decrease in evisceration staff. It is simpler to schedule production such that the number of employees is relatively constant during each payroll period. The exception to the rule is when fowl or turkeys are processed. Then a slower kill line is required with only one eviscerating line. Tom turkeys can be processed

at a rate of 800/hour; hen turkeys 1200/hour; broiler turkeys 1600/hour; and fowl 2200/hour. However, processing of birds other than broilers is rarely done for a full day, only for a few hours.

Pinecrest's production day is divided into three shifts: production, cleanup, and maintenance. The production shift begins at about 0645 hours, when the first bird is offloaded and hung on shackles. The length of the production shift is highly variable depending on the daily kill level and linespeed. The last bird may leave the chiller as early as 1430 hours or as late as 1830 hours.

The two sections of the plant, killing/eviscerating and cutting/packaging, may experience different shift lengths on the same day. On a day of very high kill the cutting/packaging section may freeze some of the poultry. On days that are short for the killing/eviscerating section, the cutting/packaging crew is apt to thaw previously frozen birds. The occasional practice of importing eviscerated poultry also varies the cutting and packaging area shift length.

Production and cleanup shifts overlap. Cleanup begins in the receiving area, after the last bird of the day is hung, and follows the end of production in each area sequentially. Cleanup shift, like the production shift, varies in length from day to day. It begins between 1400 and 1630 hours and ends between 2330 and 0200 hours.

Maintenance shift runs from 2330 hours to 0730 hours, overlapping both the cleanup and production shifts.

4.1.2 Baseline Water Use. The baseline data collection phase of the study covered the period from late November, 1978 through early February, 1979. During this period the primary objective was to characterize existing water use practices in order to identify potential areas for improvement.

Daily readings from the City of Calgary water meters were taken on weekdays. During most of the baseline period, additional daily readings were taken to determine water use by shift. The plant supplied production data in terms of birds per day and live weight killed per day.

Flow meters were installed on a number of unit processes. Other unit processes were measured with a bucket and stopwatch. Unit processes were monitored in a daily "test hour" which was used to characterize production shift water use.

Table 8 compares the operating characteristics during the baseline period with those during the year 1978. The baseline period bears close resemblance to the yearly data, so that extrapolations from the baseline phase can be considered meaningful.

TABLE 8 COMPARISON OF PINECREST FOODS LTD. BASELINE AND 1978 PRODUCTION DATA

	Baseline Period (Nov. 20, 1978- Feb. 5, 1979)	All 1978
Total Number of Days	77	365
Production Days (P)	51	245
Non-Production Days (N)	26	120
Ratio P/N	1.96	2.04
Production		
Total Birds	1 481 277	6 737 536
Birds per Production Day	29 045	27 500
Average Live Weight per Bird (kg)	1.72	1.86

TABLE 9 PINECREST FOODS LTD. BASELINE WATER USE

Total Water Used November 20, 1979 - February 5, 1979	77 725 m ³
Daily Water Use	
Production Day	1 434 m ³
Non-Production Day	177 m ³
Equivalent Annual Water Use	
Total Water Use	372 520 m ³
Production Days (245 days)	351 256 m ³
Non-Production Days (120 days)	21 264 m ³
Daily Production	
Number of Birds	29 045
Live Weight	50 100 kg
Production-Based Water Use	
Production Days	
Per Bird	49.4 L
Per kg	28.6 L
Total	
Per Bird	55.5 L
Per kg LWK	32.1 L

Table 9 summarizes the overall baseline water use data. Annual water consumption at Pinecrest is estimated to be in the order of $372\,520\text{ m}^3$, based on extrapolations from the baseline data. This is equivalent to an average daily water use, including production and non-production days, of 1020 m^3 .

Production day water use accounts for 94.3 percent of the total plant influent. The remaining 5.7 percent enters the plant on weekends and holidays. Non-production day consumption indicates leaks, and background flows such as water used for refrigeration, heating, and automatic priming of pumps.

On a "per bird" basis, water use averaged 55.5 L overall, which tends to be toward the high end of the industry spectrum. Non-production day use accounted for 10 percent of the water consumption per bird.

The average 24-hour water use on a production day at the Pinecrest plant was 1434 m^3 during the baseline data collection period. Figure 2 illustrates the variability of water use from day to day. A great many factors can affect the total daily flow in a poultry plant. Discussions in subsequent sections will clarify the reasons for variations in daily water use.

The day-to-day variations in water use did not correspond with day-to-day variations in production levels. As shown in Figure 3, the correlation was extremely weak between 24-hour water use and the number of birds processed.

Similarly, no clear relationship was found between overall water use and the number of evisceration lines in operation. Although the average 24-hour water use was less at one and one-half lines than at two lines, the use at one line was relatively high. Extensive thawing operations could have inflated the daily water use during the short period of one-line production. Pinecrest consumed 49.4 L/bird on an average production day. When only one production line ran during the first week of the study, water use per bird was very high, reaching almost 82 L on one day. At the other end of the production scale, on a day when two lines processed more than 40 000 birds, about 36 L/bird was consumed.

Because water consumption does not vary directly with production levels, there is a strong inverse relationship between volume of production and the water expended per bird (Figure 4). Water use is more efficient when production is high.

During most of the baseline monitoring period, data were collected on water use by shift. Each morning at 0600 a city meter reading was taken before the start of the production shift. The cleanup crew foreman took a second meter reading before he began

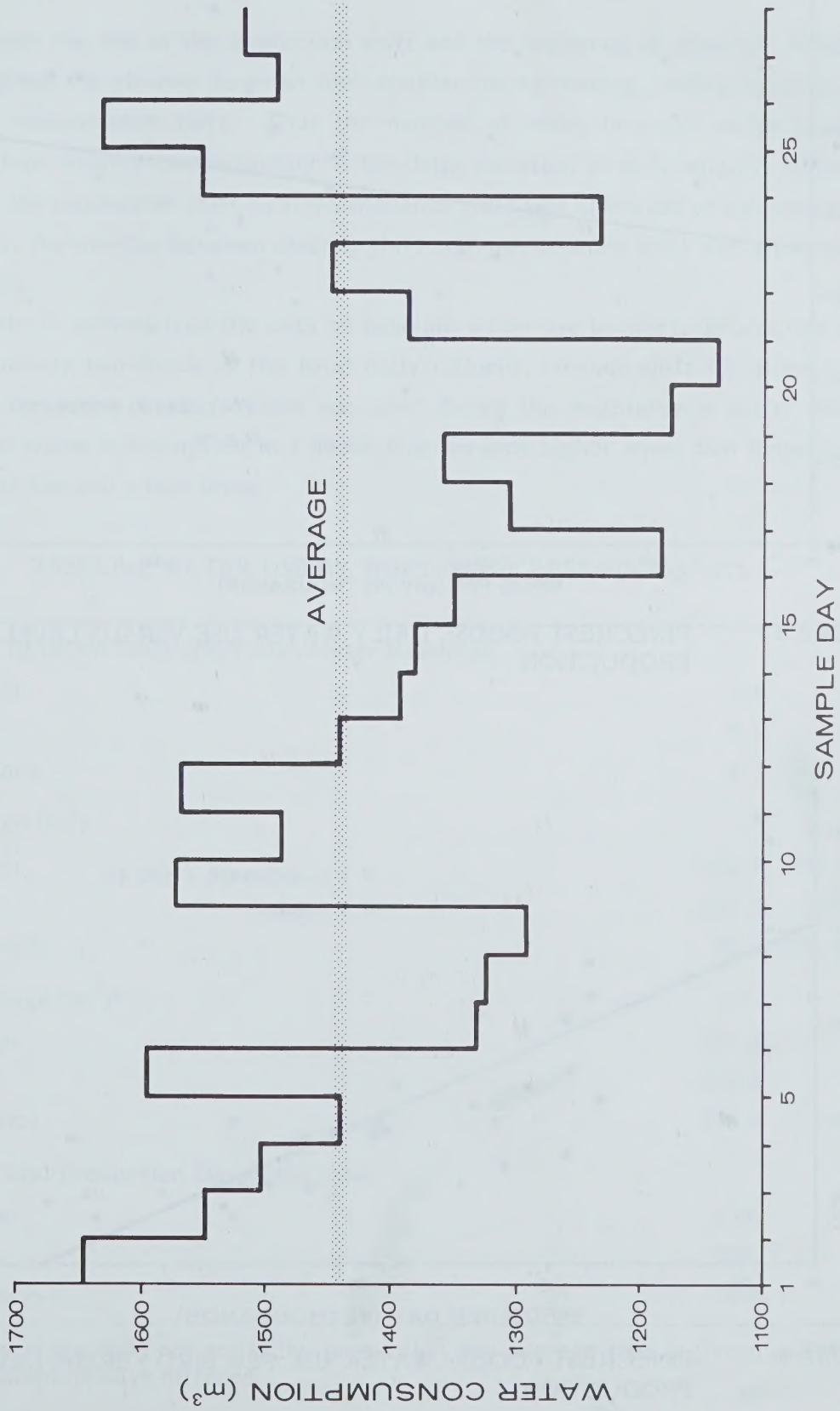


FIGURE 2 BASELINE PRODUCTION DAY WATER USE AT PINECREST FOODS PLANT

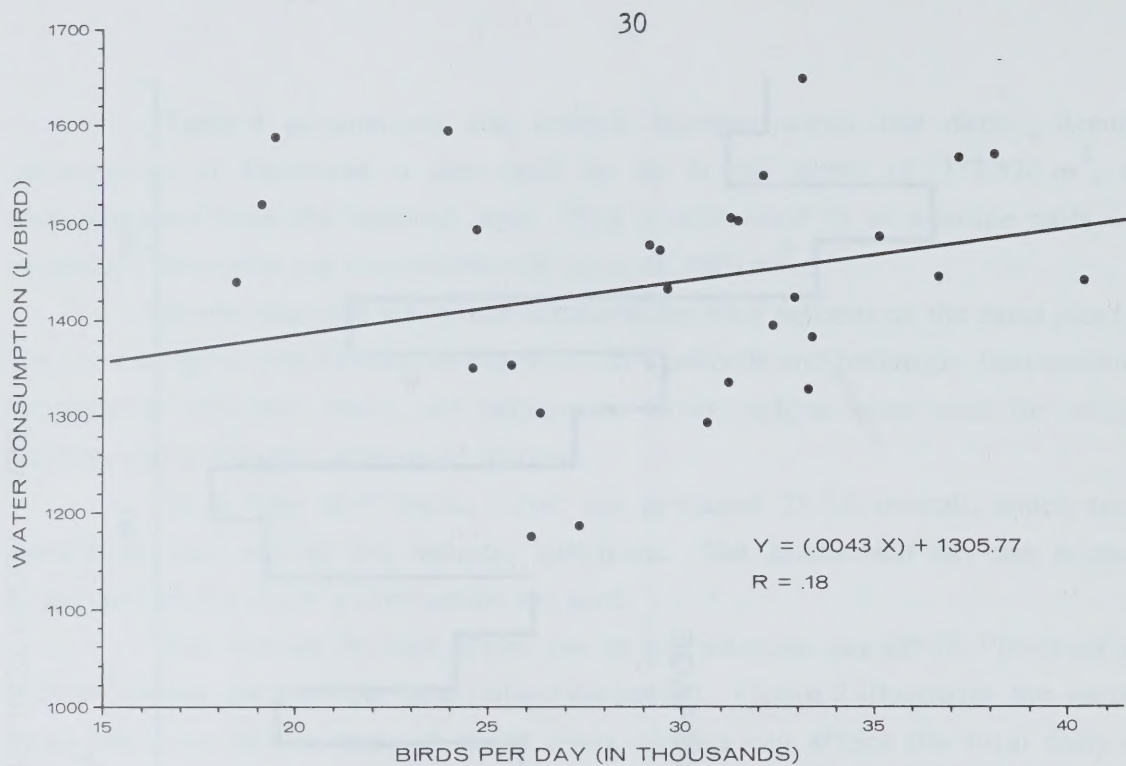


FIGURE 3 PINECREST FOODS: DAILY WATER USE VERSUS LEVEL OF PRODUCTION

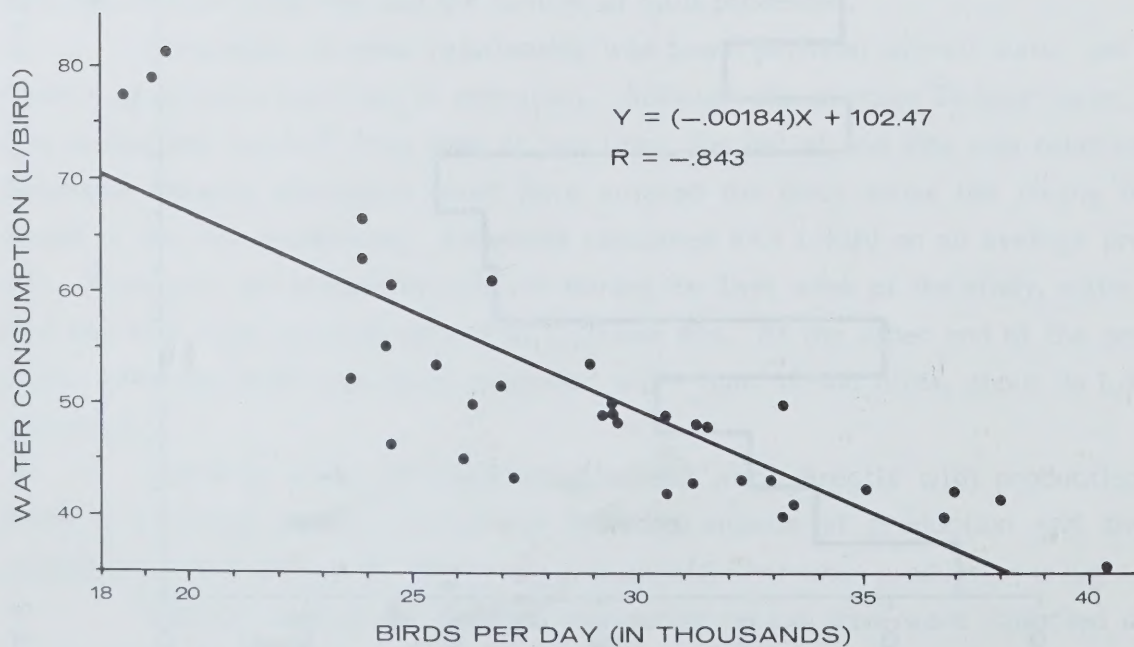


FIGURE 4 PINECREST FOODS: WATER USE PER BIRD VERSUS LEVEL OF PRODUCTION

his work, to mark the end of the production shift and the beginning of cleanup. When his work was complete the cleanup foreman took another meter reading, ending cleanup shift and beginning maintenance shift. Thus the number of hours between meter readings varied in a fashion roughly corresponding to the daily variation in shift length. However, the overlap of the production shift with maintenance shift was allocated to the production shift. Similarly, the overlap between cleanup shift and maintenance shift was allocated to the cleanup shift.

Table 10 summarizes the data on baseline water use by shift. Production shift accounted for nearly two-thirds of the total daily influent, cleanup shift for almost one-third, and the remaining small fraction was used during the maintenance shift. Hourly production shift water consumption was about five percent higher when two evisceration lines ran than at one and a half lines.

TABLE 10 BASELINE WATER USE BY SHIFT, PINECREST FOODS LTD.

Average Hours Between Start and Finish Meter Readings	
Production	9.4
Cleanup	9.9
Maintenance	4.8
Water Use Range (m ³)	
Production	666.3 - 997.0
Cleanup	301.3 - 532.6
Maintenance	93 - 250.4
Water Use Average (m ³)*	
Production	857.0
Cleanup	428.4
Maintenance	138.4
Proportion of Total Production Day Water Use	
Production	60%
Cleanup	30%
Maintenance	10%

* Total of average does not equal the production day average that is shown in Table 9 because sampling days differed.

As is typical in the poultry processing industry, all production-related activities do not occur in the production shift. For instance, the production-related operation of filling scald and chill tanks takes place during the maintenance shift. Conversely, cleanup activities occur sporadically throughout the production shift.

Data for production-day water use by unit process was determined mainly during daily "test hours" on production days between 1000 and 1100 hours. Table 11 gives a daily water balance extrapolated from test hour and other data collected in the baseline period. Certain figures in Table 11 are artificially inflated. These include those water uses which did not occur every day, such as the coop trailer wash, potable makeup to the feather flowaway, foot recovery system, and 24-hour flow of the stunner supply line. In addition, ice-making is shown at capacity rather than actual usage. Consequently, the undefined usage is artificially deflated. Three categories of water use are shown in Table 11: production processes, ancillary uses, and cleanup. The unit operations within each category are listed in decreasing order of water use.

Production processes. Production processes accounted for nearly 50 percent of the daily water used. The major water consumers among the production processes were chillers, goosenecks, bird washers, and the evisceration trough sidepan wash.

a) Chillers - Chilling of the whole birds was the largest water user of all the production processes, even when the added ice was excluded from the chilling water use total. Chilling system water consumption consisted of 36 563 L for initial fillup and 86 538 L for makeup.

Makeup water was added to the chiller at a constant flow rate which was always observed to provide an overflow. However, addition of water at a constant rate meant that the makeup water "per bird" or "per kg" was highly variable. Makeup water to the prechiller was added at varying rates from day to day; sometimes an absence of overflow was noted. Included in the makeup flow to the chillers was a leaking pipe (previously a makeup line) flowing at 6 L/min into the main chiller. An unspecified volume of chiller water was lost to the floor due to splashing caused by the action of the paddles.

b) Goosenecks - There were 46 goosenecks along the evisceration trough (Figure 5) using an average total of 110 686 L/d. None were equipped with nozzles or operational demand controls. A constant flow was required from any gooseneck at a working station, because the veterinarian-in-charge felt that hand operation of the valves would have

TABLE 11 PRODUCTION DAY BASELINE WATER USAGE, PINECREST FOODS LTD.

Unit Process	Flow Rate (L/min)	Daily Consumption (L)
Production Processes		
Chilling ^a	135.8	123 101
Goosenecks	238.0	110 686
Bird washers No.1 @ 45 904 L/d ^b		
No.2 @ 15 972 L/d ^b	177.4	88 769
No.3 @ 26 893 L/d		
Sidepan Wash	181.2	84 074
Giblet Processing ^c	124.5	61 621
Scalding ^d	70.0	53 656
Defeathering	73.0	37 093
Stunning and Killing Machine ^e	24.0	34 586
Makeup to Feather Flowaway ^f	60.1	25 880
Ice Making ^g	18.4	26 549
Sterilizers	15.3	18 020
Foot Recovery	36.8	15 451
Vent Cutting	3.71	1 782
(Sub-total)	-	681 268
Ancillary Uses		
Rotary Screen Backwash	128.0	141 321
Vacuum System (blood, lungs, packaging)	124.3	119 287
(Sub-total)	-	260 608
Cleanup		
Coop Trailers	986	169 099
Other Cleanup Shift ^h	-	287 216
(Sub-total)	-	456 315
Undefined Usage (e.g., thawing, leaks, heating, sanitary)		35 509
PRODUCTION DAY TOTAL		1 433 700

^aDaily total includes fillup of tanks but does not include addition of ice. Also does not include giblet chilling.

^bSecond washer total includes a small flow to the conveyor table backwash.

^cIncludes gizzard splitting and peeling and giblet fluming; does not include chilling.

^dDaily total includes initial fillup of tank.

^e24-hour flow to prevent water pipe freeze-up.

^fDoes not include flowaway start-up water.

^gIncludes giblet chilling.

^hExcludes cleanup shift flows previously enumerated, such as rotary screen backwash during cleanup shift.

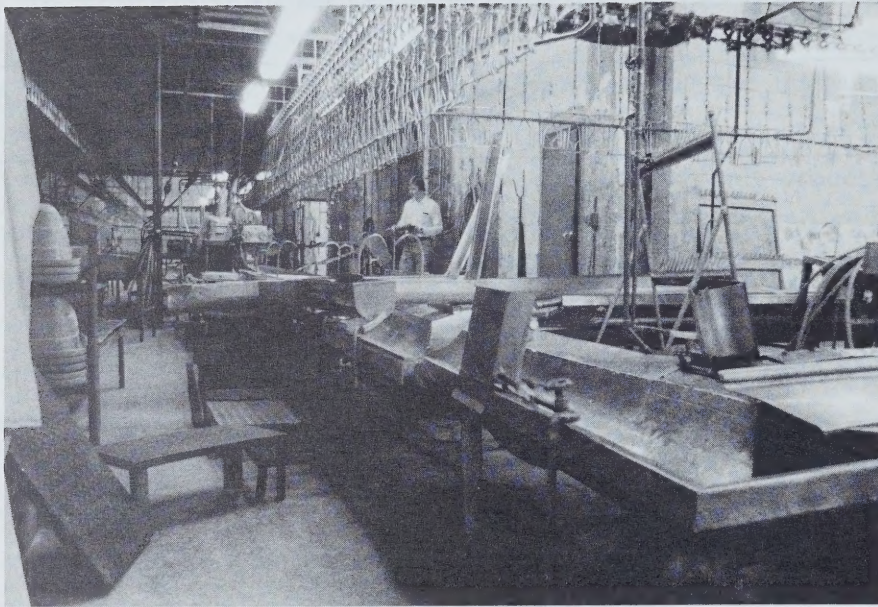


FIGURE 5 MAIN EVISCERATING TROUGH

The photo illustrates the numerous goosenecks.

resulted in a buildup of contamination on the handles. Total flow from the goosenecks was greatest when two evisceration lines, and thus all stations, were operating.

Gooseneck water flow was both copious and variable. Resultant flows varied from day to day due to changing pressure and valve settings. Flow also varied from station to station, ranging from only a trickle to a flow of 9 L/min. Because of leaking valves, some goosenecks flowed even when they were shut off. Although the staff was generally conscientious about shutting off valves during coffee and lunch breaks and at the end of the production day, there were frequent exceptions. These exceptions contributed to a general inefficiency of gooseneck water use. The inefficiency was most apparent when viewed from the perspective of utilization rates, which were as low as one per 45 seconds.

c) Bird Washers - The total flow through the three bird wash cabinets represented the third largest water consuming production process, using almost 89 000 L/d. Each cabinet was equipped with showerheads spraying in various directions in an effort to reach all parts of the birds. The direction of spray tended toward a horizontal plane rather than from above as at some plants. Sprays from the conventional domestic showerheads did not always reach the birds as intended. The second and third washers sprayed only one side of each bird due to the double evisceration line (Figure 6).

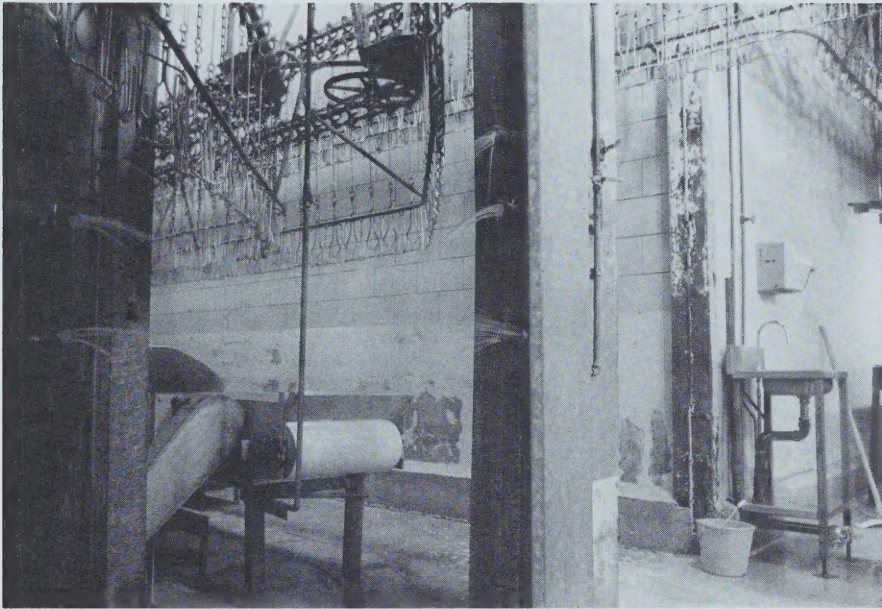


FIGURE 6 SECOND BIRD WASHER
The transfer table can be seen
behind the washer.

- d) Sidepan Wash - The sidepan wash on the evisceration trough was the fourth largest production process water user, consuming 84 000 L/d. It was intended to keep the internal walls of the troughing clean and to prevent a buildup of bacterial contamination. However, in practice the effectiveness of the wash was questionable (Figure 7). It was a low-pressure drilled-pipe arrangement built into the troughing. In spots it sent only a trickle down the sides of the trough; in other places it was nonexistent. There were severe leaks that would have required dismantling the entire trough for repair (Figure 8).
- e) Giblet Processing - Giblet processing was an area of intensive water use per unit product. It consumed more water per day than such major production processes as scalding or defeathering. Water was used for splitting, rinsing, and peeling gizzards, and for fluming hearts and livers (Figure 9). The daily total of 61 621 L does not include ice for chilling, but comprises 46 618 L for gizzard processing and 15 003 L for fluming.
- f) Scalding - Water for scalding consists of initial tank fillup, makeup water, and steam added to maintain a constant temperature. Of the 53 656 L/d total, 7778 L were used for fillup and the remainder was the makeup water.

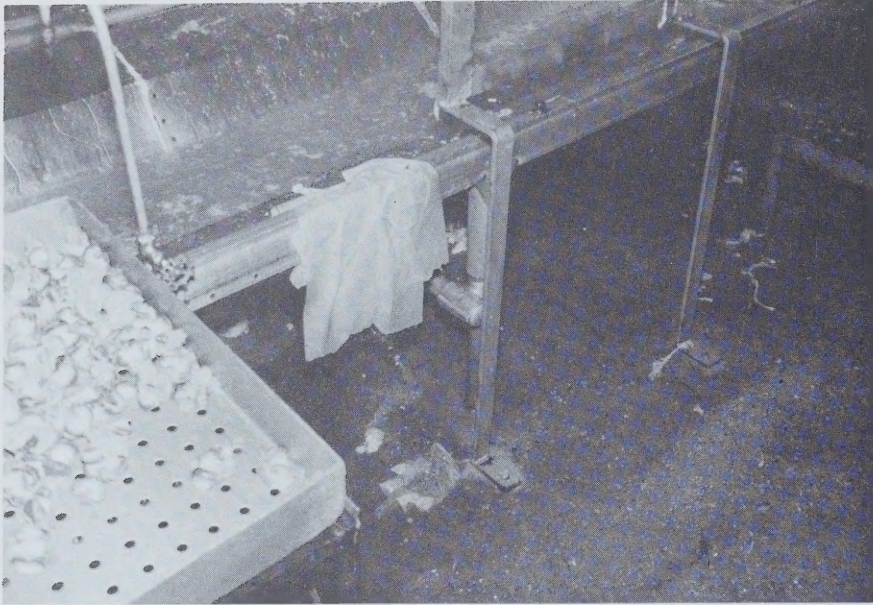


FIGURE 7 SIDEPAN WASH

Note the low pressure trickle. The paper towel has been laid over a leak, to prevent the leak from spraying workers in the vicinity.

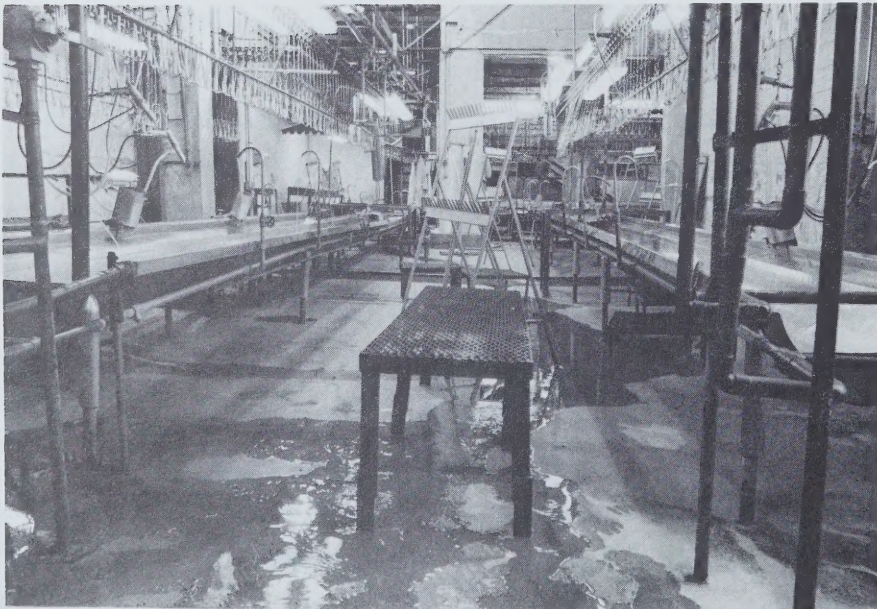


FIGURE 8 LEAKS IN EVISCERATION TROUGHING SEAMS

This photograph was taken on a nonproduction day. It was shot after water had been flowed through the troughing for a few minutes. The water on the floor illustrates the extent of leaks in the troughing.

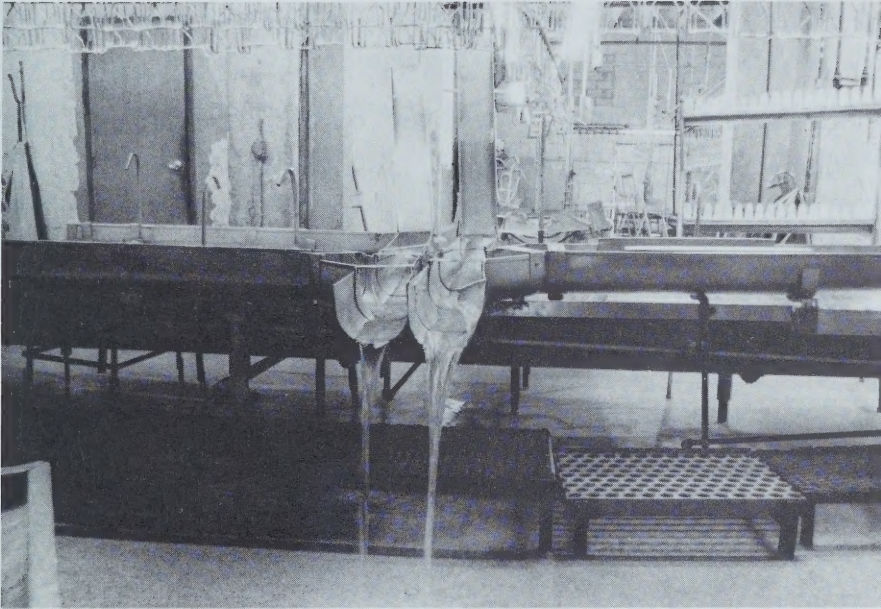


FIGURE 9 HEART AND LIVER FLUMES

When in use, plastic colanders, set on one of the platforms below, catch the giblets while the transport water drains to the floor.

g) Defeathering - Each of the two defeatherers was equipped with a drilled pipe at the top which helped to lubricate the birds and rinse the feathers off the machines and the poultry. The flow was relatively consistent from day to day, showing an overall mean of 37 093 L/d. Defeathering was an area where water use appeared inefficient; drilled pipes were used rather than appropriate nozzles for water distribution.

h) Stunner and automatic killer - Although the stunner and automatic killing machine showed a moderate flow rate (24 L/min), their combined flow was a major water consumer because it ran 24 hours a day. The line was left to flow because it ran along an uninsulated outside wall, and had a tendency to freeze up.

i) Feather flowaway - The feather flowaway was fed mainly with recycled water. After solids removal by the rotary screens, plant effluent was pumped from the adjoining pits to the head of the flowaway trench. Each morning, before the start of production, the pits were filled with potable water to begin the flow. The flowaway volume was supplemented by water from defeathering and, further downstream, the first and second wash, scalding overflow, and water from the sump when coop trailers were washed.

Nonetheless, the flume often clogged or flowed sluggishly, especially when the plant was slaughtering birds with large feathers (e.g., turkeys). To aid the flow, the plant mounted a hose at the head of the trench. In rare instances, a two-inch water pipe was opened to keep the feathers moving. This was observed only once, although plant employees reported that in summer months when there is a large kill of heavy turkeys it is more common.

In theory, the flowaway was a recycled system. In practice, the mounted hose was on during every one of the test hours conducted, flowing at 60.1 L/min. The volume of water used for the initial flowaway start-up each day was not determined.

j) Sterilizers - Sterilizers along the evisceration trough consumed a small proportion of plant water supply per minute (15.3 L). However, they were usually left to flow after the production shift and well into the cleanup shift, bringing their daily consumption to 18 020 L.

k) Foot recovery - Most of the time, the Pinecrest plant sends broiler feet along with offal to an inedible renderer. However, as often as possible, the plant sells the feet to a pet food manufacturer. It is estimated that about one-third of the total weight of feet is used for pet food. The pet food manufacturer requires the feet to be as free of feathers as possible.

After feet are removed from the carcasses following the first bird wash, the hanging conveyor transports them to the receiving area. Just prior to entering the receiving area, the feet are sprayed with water coming from two directions. Then they are automatically knocked off the shackles into a collection bin. In a further attempt to remove feathers from the collected feet, the plant ran water into the collection bin. The object was to float the feathers to the top and overflow them onto the floor, leaving only feet in the bin. When the bin was full an employee pitchforked the feet into drums, which were sent to the processor.

Out of 28 days of test hours, there were only two days that neither the foot spray nor the feather float system were in operation, although most of the time the feet were not going to be used for pet food. Some of the time only one or the other was flowing and sometimes both were on. The estimated flow from the spray when it was on was 9.1 L/min. The hose that supplied the water to float feathers from the collection bin flowed at various rates, averaging about 27.7 L/min when it was on.

There did not seem to be any pattern to the operation of the system. Sometimes it appeared that someone had forgotten to turn on the spray and/or hose when

needed. At other times they were flowing when feet were not being collected for sale. The apparatus that dropped feet off the hangers dropped many onto the floor instead of into the collection bin. Employees periodically pitchforked dropped feet into the bins or drums. This gathered feathers, which cover the receiving area floor, and added them to the collected feet. Furthermore, the drums and bins were uncovered, and liable to catch airborne feathers. It was difficult to see the difference between feet that had been through the system and those that had not.

l) Ice making - When the study began, Pinecrest was making ice with two units. The larger unit, with a capacity of 20 t/d, was the main supplier, while the smaller unit provided ice only for the prechiller and giblet chilling. With the installation of the new main chiller, the plant was able to phase out use of the smaller machine, which tended to be troublesome and unreliable.

In addition to the water directly converted to ice, the machine discharged about 4.5 L/min when in operation. Operating at capacity the main unit used an estimated 1104 L/h. In cold weather it ran about nine hours per day, mostly during the production shift. In warm summer weather the machine operates continuously.

m) Vent cutting - The hand-held vent openers use a very small amount of water for cleaning to prevent cross-contamination. Each machine uses about 1 L/min. At two eviscerating lines four vent cutters were used; at one and a half lines three were in operation.

n) Thawing - Pinecrest sometimes freezes eviscerated birds, thawing them later for cutting and packaging. Freezing occurs when the daily kill is too heavy for the packaging section to accommodate, and when the plant imports eviscerated birds from other slaughterers. Frozen birds are thawed in bins with cool, constantly flowing water (Figure 10).

During the earliest days of the study the plant was thawing heavily. One morning 19 bins were observed. A spot check of water use on another day before unit process monitoring began showed six bins of birds defrosting, using a total of 96 L/min. However, by the time measuring of individual processes began, thawing had decreased substantially. Of the 26 days for which there are test hour data, there were 14 days when no defrosting occurred. Less than five bins of poultry were thawed during the remaining 12 days. The largest volume recorded for thawing was 1655 L for the test hour. The average was only 727 L/test hour.

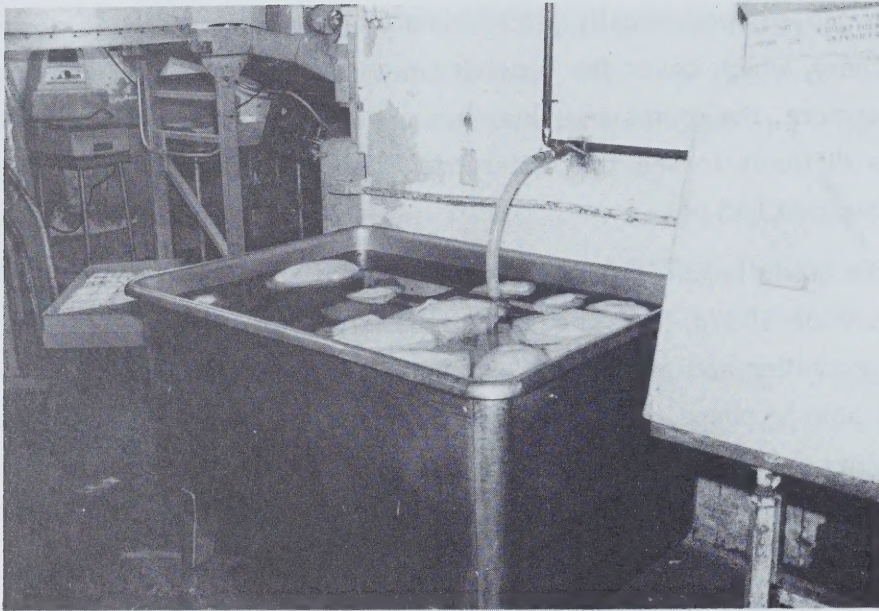


FIGURE 10 POULTRY THAWING

Initially, the defrosting area was identified as a place where some sort of conservation system could reduce plant consumption substantially. However, management explained that the level of imports to the plant was being drastically reduced. Therefore, the level of thawing activity is expected to remain low. Because of the great variation in water used for thawing and the time expended on thawing, no daily average was computed.

Ancillary water uses. Most ancillary water uses, such as for refrigeration, heating, lunchroom, and sanitary purposes, were not monitored. The rotary screen backwash and the vacuum system discharge were the two major ancillary water uses. Monitoring indicated that they accounted for 18 percent of production day water consumption.

The two rotary screens, one for evisceration wastes and the other for the feather flowaway, were each equipped with a backwash to prevent clogging. Both ran for the bulk of the production day, using a total of 141 321 L/d.

Discharge from the vacuum pumps represented another large use of water. Pinecrest uses three pumps, one for lung/kidney guns and blood collection, one for vacuum packaging, and the third as a backup. Total daily discharge amounted to about 119 287 L.

Cleanup uses. Cleaning and sanitizing at the Pinecrest plant occurs in the cleanup shift, coop washing (which takes place during both production and cleanup shifts), and intermittent spot cleaning during the production shift. Cleanup shift water usage was metered and adjusted by subtracting known production and ancillary operations during that time period. Coop washing water use was calculated from known parameters of the washing system. Water for spot cleaning was not monitored.

Adjusted cleanup shift usage was estimated to be 287 216 L. Coop washing consumed an average of 169 094 L on days when all coops were washed. Together these two major cleaning operations accounted for almost one-third of the total daily water supply.

a) Cleanup shift - Dry cleanup before washdown was practised in the receiving area. The floor was swept of feathers and manure, and feet that had overflowed from the collection bin or had missed it entirely were pitchforked into bins. The loading platforms presented a problem in receiving area cleanup. The loading platforms are wire mesh and tend to trap the feathers, dirt and feet falling on them all day, making cleaning difficult.

Employees devoted considerable time and water to spraying them with cleanup hoses and manually picking away the accumulated wastes. A considerable amount of solids fell to the swept floor, which needed to be reswept. Otherwise the material was hosed to floor drains.

Cleanup of the bleeding area was time-consuming. A worker pushed the congealed blood into a pile with a small broom, then vacuumed it away. Finally, he used a hose to dissolve the remaining dried blood and vacuumed the mixture away.

In the rest of the plant, cleanup was accomplished almost entirely with hoses. A high-pressure system was used for selected operations, such as shackle cleaning. Mostly, hoses that were under city pressure and equipped with restrictors were the major cleanup tools. In general water was used for moving solids. At times sprays were directed from greater distances than necessary.

The very largest pieces of debris on the floor had to be picked up because they would not fit through floor drain grating. Yet this was not "dry cleanup", because the solids were tossed into the evisceration trough. If water flow in the trough was insufficient to transport the material, sprays from hoses were directed down it.

There was considerable duplication of effort and, consequently, inefficient use of water. Cleanup of the defeatherers is a prime example. First, a worker hosed the accumulation of feathers from the floor into the flowaway trench. Next he hosed the tops

of the machines, which washed feathers to the floor he had just cleaned. So then he hosed the floor again. Next he cleaned the interiors of the machines. Finally, he had to hose down the floor a third time.

A "grit pit" - a box with an open top, and enclosed sides and bottom - was built into the evisceration trough. Before the rotary screens had been installed, the grit pit had been a useful device, preventing large solids from entering the sewer. A sustained blast of water from a cleanup hose was required to clean the pit at the end of the day.

Leaks at the seams connecting eviscerating trough sections resulted in small solids and grease strewn on the floor. Leaks in other equipment, such as the chillers, created similar problems elsewhere. Debris that should not have reached the floor needed to be cleaned up.

A few cleanup operations occurred only occasionally but required substantial volumes of water. An example is the flushing of sewers. Some waste streams entered floor drains with an inadequate slope for the volumes received. Objectionable odours developed. Therefore the sewers were periodically flushed with large volumes of water.

Occasionally water lines from production processes were left to flow after production and into cleanup shift. Leaks also added to the total consumption.

b) Coop trailer washing - Pinecrest has built an innovative system for washing its seven trailers with built-in coops. On either side of the walls of the truck bay in the receiving area are vertically placed manifolds equipped with spray nozzles. By driving the trailer back and forth through the sprays, the system thoroughly washes all the coops. The wash water then flows into a sump, from which it is pumped into the feather flowaway trough.

A three-inch line under about 552 kPa pressure feeds the system. The 31 nozzles are each rated at 31.8 L/min, providing an estimated water consumption by the truck trailer wash of 986 L/min. The average wash time per trailer was 24.5 min. Thus, the total water used was estimated at 24 159 L/wash.

Truck trailers cannot be washed in very cold weather because the water may freeze on the coops. Moreover, keeping the garage door to the receiving area open adversely affects the live poultry. On days when the weather is favourable, each trailer is washed and disinfected after it has been emptied of birds. On cold days, the coops are scraped and disinfected. When a whole week has been very cold, all the trailers are washed on Friday evening, regardless of temperature. Thus, the water used for this process can vary from nil to almost 175 000 L on days of full production and favourable weather, when all seven trailers are washed. On such days most trucks are washed during the production shift.

4.1.3 Baseline Waste Loads. Process effluent flows into three major wastewater streams which are ultimately sent to a dissolved air flotation unit after alum and polymer injection. Sanitary wastes comprise a fourth stream flowing directly to the city sewerage system.

The first major stream consists of wastewater flowing to numerous floor drains. This wastewater is transported directly to alum injection. The second wastewater stream flows to a rotary screen for feather separation. This stream consists of defeathering room effluent, spent truck trailer coop wash water which has been pumped into the feather flowaway trench, and minor flows from the transfer room (after hock removal) and the beginning of evisceration. The third wastewater stream goes to the viscera rotary screen. Its major source is the evisceration trough. The floor trench that directs the flow to screening runs along part of the packaging area, so the stream receives small amounts of floor drainage from that section of the plant.

Materials recovered from screening the second and third streams are augered into containers for eventual transport to a rendering plant. Effluent flowing through the screens falls into two connecting pits, one underneath each screen, where a certain amount of settling of small solids occurs. Some of the effluent in the pits is recycled back to the feather flowaway. The rest is pumped to alum injection.

Pinecrest had installed a new dissolved air flotation unit a few months prior to the study. At about the same time the plant sealed off a floor drain in the blood collection area through which blood had seeped into plant wastewater. The concentrations of BOD₅, suspended solids, and oil and grease in the final effluent were within municipal bylaw limits (300, 300 and 100 mg/L, respectively). High water use resulted in a relatively dilute effluent, and the air flotation unit removed some of the waste loading.

Pinecrest maintained its own sampling program. Every Wednesday, plant personnel took half-hourly samples of wastewater discharged from the flotation unit, and composited them into a production shift sample. The sample was analyzed for BOD₅, suspended solids, and oil and grease. Based on composite samples taken on eleven different days, average concentrations were:

BOD ₅	-	279.2 mg/L
Suspended Solids	-	162.9 mg/L
Oil and Grease	-	51.6 mg/L

Results showed relatively little variation in concentrations among individual samples.

Data supplied by the plant was applied to 24-hour water use data to determine a total weight of BOD₅ discharged. Although this may seem an artificial method of computing waste loads, because it is based on the invalid assumption that 24-hour concentrations equal production shift concentrations, it closely resembles the method used to compute municipal surcharges. The municipality collects concentration data only during the production shift and then applies that data to total plant water use. Applying the concentrations to 24-hour water use yields:

BOD ₅	-	408.7 kg/d
Suspended Solids	-	238.6 kg/d
Oil and Grease	-	75.3 kg/d

Production figures were then obtained to standardize the waste loadings with respect to volume of kill. The results were:

BOD ₅	-	7.96 kg/1000 kg LWK
Suspended Solids	-	4.65 kg/1000 kg LWK
Oil and Grease	-	1.47 kg/1000 kg LWK

The weight of pollutants per weight of unit product as calculated above compared favourably with the industry as a whole (see Appendix A). Moreover, Pinecrest was not being assessed a surcharge by the municipality, because concentrations were within the allowable limits. Thus, on the whole, waste load was not identified as a problem area.

Nonetheless, there was the concern that a reduction in water use might be accompanied by a commensurate pollutant rise in discharge concentrations, resulting in the levying of a surcharge. Therefore, potential areas for in-process waste load reductions were identified.

- 1) Blood dripped onto the floor at several places along the production line between the first bird wash and vent cutting operations. The blood eventually flowed into the plant effluent system, mostly into the feather flowaway trench.
- 2) Oil sacs and blood fell to the floor at the oil sac removal station. The operation was conducted over small portable sections of eviscerating trough. Blood and oil sacs accumulated and then fell off the ends of the troughing or sometimes missed the troughing entirely.

- 3) Chicken heads containing undrained blood often fell into the eviscerating trough. Heads were generally collected and chilled for sale as animal food. Nonetheless the collection procedure was sometimes lax.
- 4) Cleanup procedures, both during the production shift and the cleanup shift, tended to add unnecessarily to the plant's waste load. One of the more blatant examples was the dumping of collected oil sacs into the head of the evisceration trough. The sacs were then flumed the entire length of the trough, screened, and augered for rendering. It can be assumed that some additional pollutant load was imparted to the wastewater as a result of the fluming process.

4.1.4 Plant Attitudes. Literature on in-plant water and wastewater management stresses the importance of attitudes and accurate knowledge as foundations for successful conservation programs. From the inception of the study, Pinecrest's management expressed strong support for the project's goals. This support was viewed as a crucial factor in its ultimate success. The veterinarian-in-charge and regional inspection officials were extremely cooperative, and took great interest in providing input to the project.

Plant workers did not appear to be informed about the economic consequences of excessive water consumption. The attitude among plant employees seemed to be that, as far as government inspection was concerned, "the more water, the better". Sometimes plant workers mistook study personnel for outside inspectors, and increased water use. The belief "the more water, the better" is indicative of a lack of knowledge about efficiency of water use. The following example illustrates how that misunderstanding can affect a water conservation program.

An employee, on being questioned about a leak in a large hose in the receiving area, explained that the hose was used for washing the receiving area floor. Since the leaking water was flowing along that floor, he saw no reason to immediately repair the leak. In his eyes, the leaking water was accomplishing its intended job.

This apparent lack of concern and knowledge regarding water conservation is reflected in Pinecrest's relatively high water consumption during the baseline monitoring period.

4.1.5 Modifications. In February and March, 1979, modifications were made to plant equipment and procedures in an effort to reduce water use and waste loads. This section describes the modifications and discusses their results. The savings achieved by each

modification were calculated based on City of Calgary water and sewer service charges (Appendix C).

Vacuum Seal Water As Backwash For Rotary Screens. Potable water was not necessary for backwash on the rotary screens, where excessive volumes were being used. Vacuum seal water, a relatively clean effluent, was being lost to sewer.

Vacuum seal water was, therefore, collected and pumped to the rotary screens. The vacuum seal water was piped into a 45-gallon (205-L) drum which served as a collection basin. A submersible pump was placed in the drum and the discharge from this pump was piped into the original spray system on each of the rotary screens (Figure 11). A small amount of steam was added to the collection basin to warm the water.

The cost of this modification, including piping alterations to facilitate cleanup in the area, was:

Materials

Submersible sump pump	\$134.25
Pipes, valves, fittings	
Misc. materials	<u>\$243.63</u>
Subtotal	\$377.88

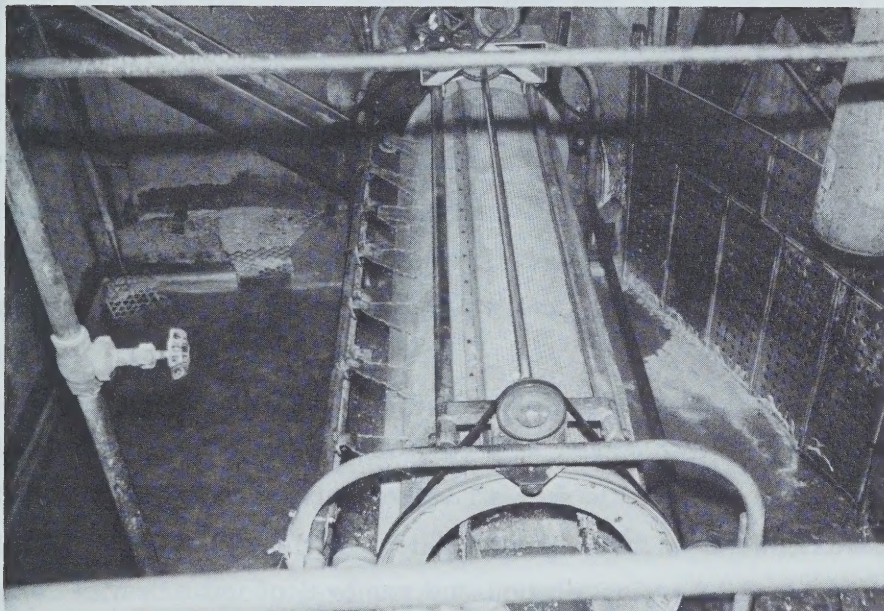
Labour

24 hours @ \$10/hour	<u>\$240.00</u>
Total:	\$617.88

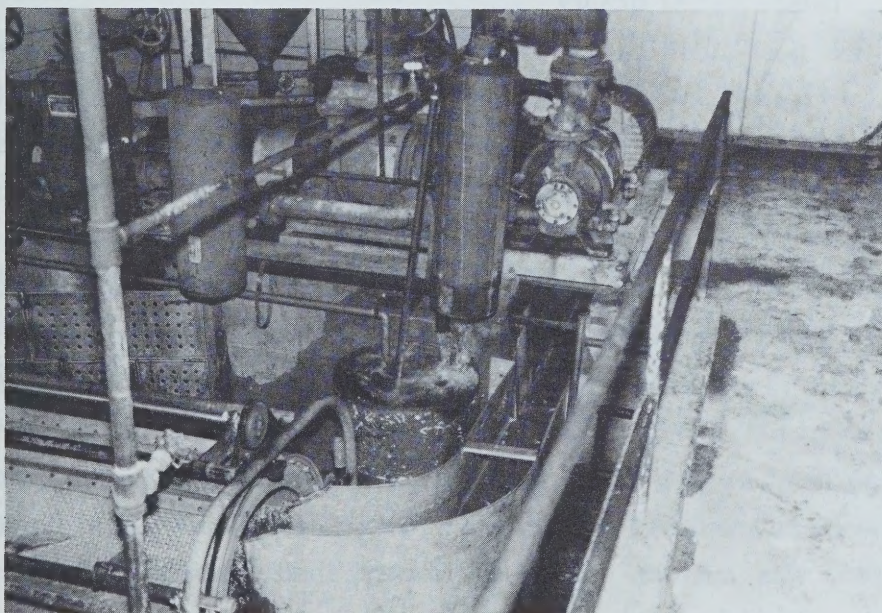
The discharge from the vacuum pumps was conveniently located to permit its re-use as backwash for the rotary screens. This modification provided the single greatest saving in water use of the project.

Potable water input to the rotary screens was practically eliminated. Total savings were 141 321 L/d. When all three pumps were running, approximately 9100 L/h were collected. Since one of the vacuum pumps serves only as a backup, only about 6800 L/h were collected during proper operation. Since the submersible pump has a capacity of 5455 L/h, not all the collected water was recycled.

In addition to small amounts of steam, potable input was also needed to wash the screens at the end of cleanup. A cleanup hose was used. However, this had been standard procedure previously, so did not constitute an additional water use.



11A



11B

FIGURE 11 VACUUM PUMP SEAL WATER REUSED FOR
ROTARY SCREEN BACKWASH

In case the vacuum pumps were not operating during the last hours of the cleanup shift, or a pump failure occurred, the original system was left in place as a backup system.

The elimination of 141 321 L/d saved \$12.87 in water costs and \$10.30 in sewerage costs per day. The payback period would be less than two months.

Modifications To Goosenecks and Sidepan Wash. Goosenecks along the evisceration trough ran constantly and their flow rates were excessive. The sidepan wash did not appear to have an appreciable effect on the cleanliness of the trough. In addition, it leaked heavily in several places.

Modifications made included the installation of knee activated on-off valves, flow control valves, and several types of nozzles. A pressure regulator was also tried but was unsuccessful. Employees were reminded to shut off valves at breaks and at the end of the day. The sidepan wash was eliminated where possible.

These modifications, including installation and removal of unsuccessful components, cost:

Materials	\$ 593.49
Labour, 48 hours @ \$10/hour	<u>\$ 480.00</u>
Total	\$1 073.49

During the entire post-modification monitoring period, the average water reduction was 34 percent. However, by the final two weeks of monitoring, after all experimentation with the goosenecks and sidepan wash had been completed, an average daily reduction of 118 178 L had occurred: from 194 760 L/d before modifications to 76 582 L/d after. This is equivalent to a 61 percent reduction.

The employees and inspectors along Pinecrest's evisceration line had been accustomed to washing their hands often with copious amounts of water. Study personnel had observed other plants where employees used much lower flows and washed their hands as frequently, so it was known that reductions in volumes were possible. It was not the intention to reduce the high level of cleanliness along the evisceration line; rather, the objective was to maintain the same level of sanitation with lower flows. The major obstacle, it was discovered, was custom. Because workers had been used to the convenience of constant flows, they generally felt unhappy with the initial modifications.

Some of the gooseneck and sidepan lines were repiped in order to have one feeder line for installation of a pressure regulator. However, it became clear that the pressure drop in pipes during full production was such that a pressure regulator was

unnecessary. Even at its maximum setting, pressure was insufficient. Therefore, the regulator was removed.

The goosenecks were modified to allow various fittings at their outlets. "Water Misers" were installed at the windpipe pulling stations, which had low utilization rates. Water Misers had been recommended in the literature and by plants visited in the course of the study as inexpensive demand-activated gooseneck controls. Although they have a tendency to break easily, they are inexpensive and simple to replace. However, employees were dissatisfied with their operation. They found they had to use two hands (one to push the lever up while the other hand is rotated in the stream of water) to achieve the level of cleanliness they were accustomed to. To wash both hands took about twice as long as it had previously taken. Therefore, the Water Misers were removed.

A somewhat more successful attempt at demand-activation was the installation of knee- and hip-controlled valves. Foot control had been considered, but that idea was discarded because of potential inconvenient cleanup, vulnerability to damage, and user fatigue. Cost and delivery time were prime considerations, and knee-activated gooseneck set-ups were rather expensive and unavailable locally. Therefore, the controls were fashioned by study and plant personnel using "36 Valves" (manufactured by Spraying Systems Co., Wheaton, Ill.), purchased for \$16.50 each. The 36 Valves were installed on goosenecks at inspector's stations and at several work stations. The innovation was unsuccessful at the inspector's station. There the valves were quickly locked into the "on" position. Plant employees, however, accepted the change, reducing the flow rate through their goosenecks in one case from about 3.6 L/min to about 0.9 L/min.

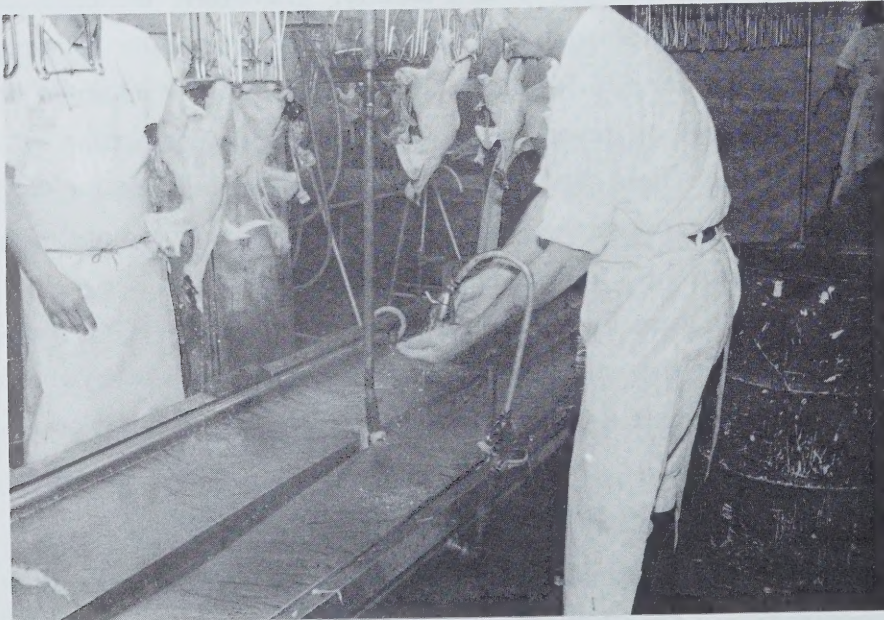
Demand-activated controls were least convenient at stations with high utilization rates. Although it is believed that the valves could be successfully used everywhere along the eviscerating line, it would require a period of strict enforcement while workers grew accustomed to the devices (Figure 12).

Three different nozzle types were tried with the following results:

- a) An ordinary domestic showerhead was installed at an inspection station. The flow rate was actually higher than previous (396 L/h versus 372 L/h), but washed hands more effectively (Figure 12).
- b) A "Veejet" flat spray nozzle H1/4VV6504 (manufactured by Spraying Systems Co.) was installed at an inspection station. Flow was reduced 50 percent from 120 L/h to 60 L/h. User found the severe reduction disturbing, and considered flow rate inadequate.



a) Goosenecks flow only on demand activation.



b) At the inspectors' stations the valves were locked into the "on" position. Domestic shower nozzles actually used more water than goosenecks with no nozzles. However, the inspectors found them quite effective.

FIGURE 12 EVISCERATION TROUGH GOOSENECKS

- c) The same Veejet nozzles were installed on goosenecks at vent opening and exposure of viscera stations. Similar Veejet flat spray nozzles with greater flow capacities (H1/4U6510) were installed at giblet handling stations and crop pulling. Flow reductions ranged from about 25 percent to 50 percent. Again, employees were displeased with the obvious flow reductions, and some of the nozzles were removed.

The most successful device was found to be a Dole flow control (Eaton Corporation, Carol Stream, Ill.). The flow control, installed inconspicuously in the supply line, maintains a preselected flow rate regardless of the water pressure. Adjustable flow controls were used, so that an optimal flow rate could be determined and set. Several were set at 4.5 L/min and installed in goosenecks. Workers could open a tap to full flow, yet only receive a predetermined amount of water. The flow reducer was successful because it was inconspicuous and virtually tamper-proof. Workers simply did not appear to notice the change.

The sidepan wash was eliminated where possible. Initially, a timer was proposed to run the sidepan wash 20 percent of the time, similar to the innovation at Gold Kist. However, the final conclusion, after consultation with the veterinarian-in-charge, was that the sidepan wash was ineffective and unnecessary. In some areas the sidepan wash was tied into the gooseneck piping and major modifications would have been required to eliminate it. In other places the valves were simply shut and taps removed.

The average savings during the post-modification period were 65 354 L/d. Water costs were reduced by \$5.95/d and sewerage costs by \$4.76/d. Payback period for the modifications, including those that were abandoned, would be less than six months. However, final savings achieved after all fine tuning were considerably greater than average savings. The reduction of 118 178 L/d in the last two weeks of monitoring represents a reduced water and sewerage cost of \$19.39/d. Payback is thus less than three months.

Based on the experience gained during these modifications, it is suggested that demand-activated valves be restricted to use on goosenecks with low utilization rates, at least at first. Workers at stations with high utilization rates, such as inspectors' and giblet harvesting stations, tend to balk at the relative inconvenience of demand activation valves. It is also suggested that changes be implemented in stages, if possible. For instance, install flow controls and gradually reduce their settings, giving workers plenty of time to grow used to the reductions. Nozzles may assist in increasing the efficiency of low volumes, and give the "feel" of a more forceful flow.

Plants with a sidepan wash on eviscerating troughs may wish to seriously consider removing it provided this is acceptable to the veterinarian-in-charge. At Pinecrest, edible product did not come in contact with the trough, and the chance of contamination via airborne bacteria was judged to be negligible. The troughing was low enough that workers' hands generally did not touch it. Quick hosing down of the trough at breaks and between loads of birds appeared to adequately clean it.

Redesign of Bird Washers and Modifications to Defeathering Machines. Defeathering is discussed here with the bird washers because piping was altered such that the defeathering machines and first bird washer shared a feeder line. A flow meter was installed on the shared line.

A drilled pipe originally supplied water to the defeathering machine for lubrication and feather removal (from the machines). Because drilled pipe arrangements are generally inefficient means of applying water, this was considered an area for improvement. The pipe ran only along one side of the machine, and the other side was subject to a buildup of feathers.

Showerheads used on the bird washers were inefficient; the direction of the sprays followed no apparent pattern - they were often observed spraying the air rather than the birds. When both hanging conveyor lines were in operation (at 1 1/2 and 2 eviscerating lines) only one side of each bird was washed in the second and third bird washers.

In modifying these systems, the defeathering units were left basically intact except that nozzles were installed in place of drilled pipe.

The bird washers were redesigned. A manifold was installed in the center of the cabinet so that both sides of the birds were washed. Spray nozzles were installed such that the pattern of the wash was top first, then middle, then bottom. Nozzles were placed on manifolds which could be swivelled, and the lowest nozzles had separate valve controls, to be turned on only for large birds. These features provided flexibility for washing various types and sizes of poultry.

The pipe supplying the second bird washer also supplied the backwash on a small conveyor table in the transfer room. The backwash, a drilled pipe arrangement, was equipped with spray nozzles.

The cost of modifications was:

Materials	\$ 506.44
Labour, 38.27 hours @ \$13.83/hour	\$ 529.44
Total	\$1 035.88

Initial modifications to the defeatherers and washers decreased water use. However, they were eventually judged to have a negative effect on product quality and were removed.

A pressure regulator which reduced pressure too severely had been installed on the defeatherer. At the same time the drilled pipe was replaced by nozzles which sprayed in a too-fine pattern. Cuticle was not being completely removed from the poultry, and the production line was halted. The pressure regulator was removed, the nozzles replaced by more appropriate ones, and a hose was temporarily rigged up to spray additional water into the machines.

For the next couple of weeks problems with patches of yellow skin remaining on the birds were sporadically encountered. The exact reasons for the improper cuticle removal were never satisfactorily determined. What made the problem so perplexing was its inconsistency. Some days, two or three truckloads of birds would be fine, but then the next load would again show problems.

Several weeks after the study's completion, Health of Animals officials from the regional and Ottawa offices inspected Pinecrest and found the new bird washers unacceptable. The inspectors' criticism was that loose feathers sticking to the skin were inadequately washed off by the first and second washers.

Consequently, the plant repiped the line to defeathering machines to supply more water. Also, it redesigned and installed washers that were judged acceptable. They returned to showerheads, which point downward from the level of the shackles. The key to the new system's success seems to be the relatively small number of showerheads - six on the first washer and four on the second. Concentrating the flow through a very few sprays results in a given volume of water carrying heavier force. Gravity action on the downward-moving sprays also helps to increase the force of the water, and so persistently sticking feathers are more easily washed away.

The cost to re-modify the bird wash and defeathering equipment was \$887.12. Thus the total cost of bird wash and defeathering modifications was \$1 923.00. Due to the problems encountered, there was no return from a decrease in water use.

In Canada, where cuticle is removed from poultry, skin tends to be sticky. Insufficient water in defeathering increases the tackiness, so stray feathers sticking to the skin can be a problem. It is suggested that before any alterations are made to defeathering machines, they should be inspected thoroughly and any worn fingers should be replaced. Similarly, the scalding should be in good working order before reducing flows to defeathering.

A better way to judge the effectiveness of modifications would have been to alter the defeathering water supply system first, leaving the old bird washers intact. After observing the results of defeathering operations, then the washers could have been modified. Modifying both simultaneously prevents evaluation of the independent effects of each change.

Feather Flowaway Modifications. The flowaway trench clogged frequently and potable water was being used to improve flow.

The trench was modified by lining it with galvanized sheeting from the point of the recycle line discharge to the first bird washer (11 m). The point of discharge was relocated to provide a more evenly distributed movement of water down the flowaway.

This modification cost:

Materials	\$107.63
Labour, 13.58 hours @ \$10/hour	<u>\$135.80</u>
Total	\$243.43

The reduced friction and even flow combined to increase efficiency of feather transport, so that water addition with a hose was no longer needed. Since plugging of the flume was eliminated, some labour saving was also achieved. Total water savings were 25 880 L/d. Payback, at \$4.25/day in reduced water and sewerage costs, would be less than three months.

Modifications to Foot Recovery System. The addition of a constant flow of potable water to bins of collected feet did not effectively float feathers away. Feet missing and overflowing the bin to a littered receiving area floor were mixed with the "cleaned" feet in collection bins, defeating the purpose of the float system.

A hopper bin was constructed to protect the collected feet from mixing with feathers and debris in the receiving area. The hopper was constructed to fit directly underneath the foot knock-off point on the conveyor. It stood on legs with space underneath to place a 45-gallon (205-L) collection drum. A sliding panel between the hopper bin and the drum permitted a full drum to be replaced with an empty one, while no feet fell to floor in the interim (Figure 13). The spray system was left intact.

The cost of this modification was:

Materials	\$ 73.85
Labour, 41.6 hours @ \$10/hour	
+ 2.5 hours @ \$16/hour	<u>\$456.00</u>
Total	\$529.85

The labour shown at \$16/hour reflects fabrication work by a sheet metal shop.

Water saved was 11 083 L on production days when feet were being collected. Water and sewerage costs of \$1.82/day were saved on days when feet were collected. If feet are collected an average of three days a week, the cost of the modification will be recovered in two years.

Not all of the expected improvements in foot recovery resulted from the hopper bin collection system. It was meant to be a labour- as well as water-saving device, but insufficient employee attention during the production shift nullified the potential for labour saving during cleanup and diminished the system's effectiveness in keeping sprayed feet free of floor grime.

The system was designed to save labour in two ways. Previously, feet were collected in bins and then transferred into collection drums. The new system eliminated the transfer. Also, because the new system minimized the chances of feet falling to floor, it was meant to save the tedious work of transferring the feet from the floor to drums (about one man-hour). Unfortunately, the system demanded frequent checks to remove each full drum and replace it with an empty one. It took about 15 minutes for a barrel to fill, and required three minutes of employee time to change the barrel. When used properly, about 60 feet/hour reached the floor, due to erratic functioning of the knock-off apparatus. This job was not undertaken conscientiously, and feet in the drums frequently overflowed onto the floor (Figure 13). Nonetheless, the hose to float feathers from the feet was eliminated, with no detrimental effect on byproduct quality.

The sprays providing an initial wash to the feet prior to knock-off from the shackles were left in place. It was concluded that they did an acceptable (although not optimal) job of removing stray feathers. As a supplement to these sprays, the redesign of the first bird washer included a spray to the feet.

This example illustrates the importance of employee cooperation to the success of a water conservation program. It appears in retrospect that a hopper bin with much larger capacity would have improved the system's workability. Then, the slide panel could have been shut, the hopper filled, and the feet transferred to several drums in a few minutes. The need for close attention would not have been so great.

Regulation of Pre-Chiller and Chiller Makeup. Makeup water to the chilling system had not been regulated on a per bird basis. The main chiller makeup line flowed at a set rate, regardless of the throughput. Makeup to the prechiller flowed at various rates, but was sometimes insufficient to maintain an overflow.



a) Hopper bin with collection drum



b) Feet overflow full drum

FIGURE 13 FOOT RECOVERY

An attempt was made to calibrate the flow to the chilling system so that the U.S. standard of about 1.9 L/broiler was maintained. There was no cost for the modification.

The results of this modification were generally positive. Plant personnel were made aware of the possibilities for water conservation by regulating chilling system makeup. However, the Pinecrest plant has a very uneven throughput over the production day. The time and attention needed to readjust the makeup lines throughout the day was not available. Nonetheless, the staff made an attempt to minimize flow to the chiller, resulting in a savings of 21 340 L/d, equivalent to \$3.49/day in reduced water and sewerage costs.

Re-use of Chiller, Compressor, and Ice Machine Overflows for Offal Transport. When the sidepan wash and gooseneck flows were reduced, there was a risk of being left with insufficient volume in the evisceration trough to flow away offal.

To reduce this risk, overflow from the main chiller was pumped through to the head of the evisceration trough. Compressor cooling water and ice machine overflow were also tied into the recycle line.

The cost of this modification was:

Materials	\$ 521.49
Labour, 37.38 hours @ \$13.87/hour	<u>\$ 518.43</u>
Total	\$1 039.92

The system had no appreciable effect, but was in place in case offal flowaway volume had decreased dramatically. The recycle to the offal flowaway, as it turned out, was unnecessary for transport in this particular case.

Modifications to Trailer Coop Wash. The trailer coop wash used excessive amounts of water. Most of the cleaning appeared to occur in the first 10-15 minutes of each wash.

The worker who washed the coop trailers was instructed to limit initial wash time to ten minutes. He was to then examine the results and only extend the length of the wash if his inspection showed a definite need. There is no cost associated with the modification.

The post-modification wash time per trailer averaged 13 minutes, a 47 percent reduction, equal to a savings of 11 345 L/wash. Projected water savings on days when all trailers are washed equal 79 412 L. On days when all trailers are washed there may be a favourable effect on final effluent due to a reduction in hydraulic loading to the flotation cell. Total daily savings in water and sewer costs were \$7.23 and \$5.78, respectively.

Installation of Drip Troughs. Blood from hanging poultry dripped to the floor between the transfer room and the evisceration trough. Isolated sections of troughing where oil sacs were removed caught some blood, but overflowed at the ends onto the floor.

Freestanding metal drip troughs were constructed and placed under the hanging conveyors (Figure 14). The space along the line immediately after transfer and before singeing and the second wash cabinet was too cramped for troughing.

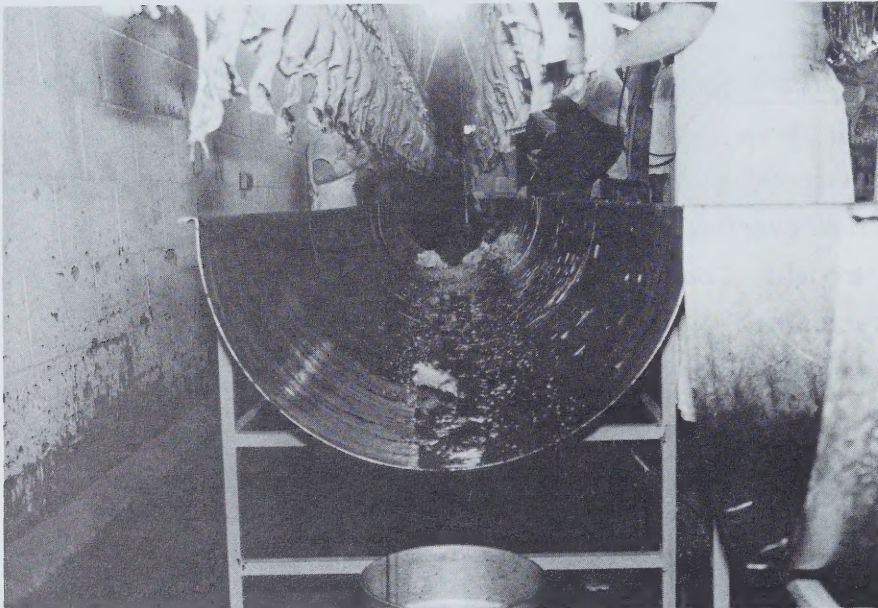


FIGURE 14 FREESTANDING TROUGHING

During lunch and coffee breaks workers transferred collected blood and oil sacs into 45-gallon drums. They also squeegeed as much blood as possible from the floor and put it in the drums.

The cost of these modifications was:

Materials	\$268.80
Labour, 14 Hours @ \$18/hour	<u>\$252.00</u>
Total	\$520.80

Although unmeasured, a small volume of water was likely saved by reducing the necessary hosing of the floor in this area. An undetermined mass of pollutants was prevented from entering the wastewater by the dry collection of blood and oil sacs.

Modifications to Cleanup Procedures. Minimal dry cleanup was practised. Cleanup procedures were often inefficient and redundant.

Brooms, squeegees, shovels, and barrels were provided. The principles of dry cleanup were explained to the cleanup crew, and some suggestions made for streamlining procedures. The men were particularly cautioned to avoid placing solids in the evisceration trough, but rather to shovel them into barrels. The plant covered the grit pit on the evisceration trough and attempted to seal some of the larger leaks in the troughing.

The total cost of these changes was minimal, and was absorbed by the plant.

Total water savings averaged 43 541 L/cleanup shift. In addition, an undetermined volume of water was saved by the drier cleanup procedures during the production shift. Water and sewerage costs were reduced by a total of \$7.15/day.

4.1.6 Effects of Modifications on Water Use and Waste Loads. During the period from March 14 through May 2, 1979, after all modifications were complete, water use and waste loadings were monitored. Table 12 compares the operating characteristics of the post-modification period with the baseline monitoring period. There is a 15 percent difference in the ratio of production to non-production days during the two periods. Thus, a daily equivalent water use figure would not provide a meaningful basis for comparison. Production in terms of both number of birds and average live weight per bird were slightly higher during the post-modification period. However, the percentage difference is too small to interfere with comparisons of water use on a per unit product basis.

Table 13 compares the baseline water use data with data from the post-modification period. Water use on production days was 28.1 percent lower after the modifications. On a per-bird basis the savings were 31.6 percent.

However, the overall reductions are moderated by a net increase in non-production day water use, discussed in a subsequent section. Combining production and non-production day water use figures, and calculating overall savings yields:

Equivalent Annual Savings	97 732 m ³
Savings per Bird	15.4 L
Savings per kg LWK	9.4 L

These savings represent reductions in the order of 26 to 29 percent.

Figure 15 shows the pattern of production-day water use in the post-modification monitoring period. Water use continued to be variable from day to day, but

TABLE 12 COMPARISON OF POST-MODIFICATION AND BASELINE OPERATING DATA, PINECREST FOODS LTD.

	Post-Modification Period (March 14- May 2/79)	Baseline Period (Nov. 20/78 - Feb. 5/79)
Total Number of Days	49	77
Production Days (P)	34	51
Non-Production Days (N)	15	26
Ratio P/N	2.27	1.96
Production		
Total Birds	1 031 554	1 481 277
Birds per Production Day	30 340	29 045
Average Live Weight per Bird	1.77 kg	1.72 kg

TABLE 13 COMPARISON OF POST-MODIFICATION AND BASELINE WATER USE DATA, PINECREST FOODS LTD.

	Post-Modification Period (March 14- May 2/79)	Baseline Period (Nov. 20/78 - Feb. 5/79)
Total Water Used	37 815 m ³	77 725 m ³
Daily Water Use		
Production Day	1 027 m ³	1 434 m ³
Non-Production Day	192 m ³	177 m ³
Daily Production		
Number of Birds	30 340	29 045
Live Weight	53 867 kg	50 100 kg
Equivalent Annual Water Use		
Total Water Use	274 788 m ³	372 520 m ³
Production Days (245 days)	251 688 m ³	351 256 m ³
Non-Production Days (120 days)	23 100 m ³	21 264 m ³
Production-Based Water Use		
Production Days		
Per bird	33.8 L	49.4 L
Per kg LWK	19.1 L	28.6 L
Total		
Per bird	40.1 L	55.5 L
Per kg LWK	22.7 L	32.1 L

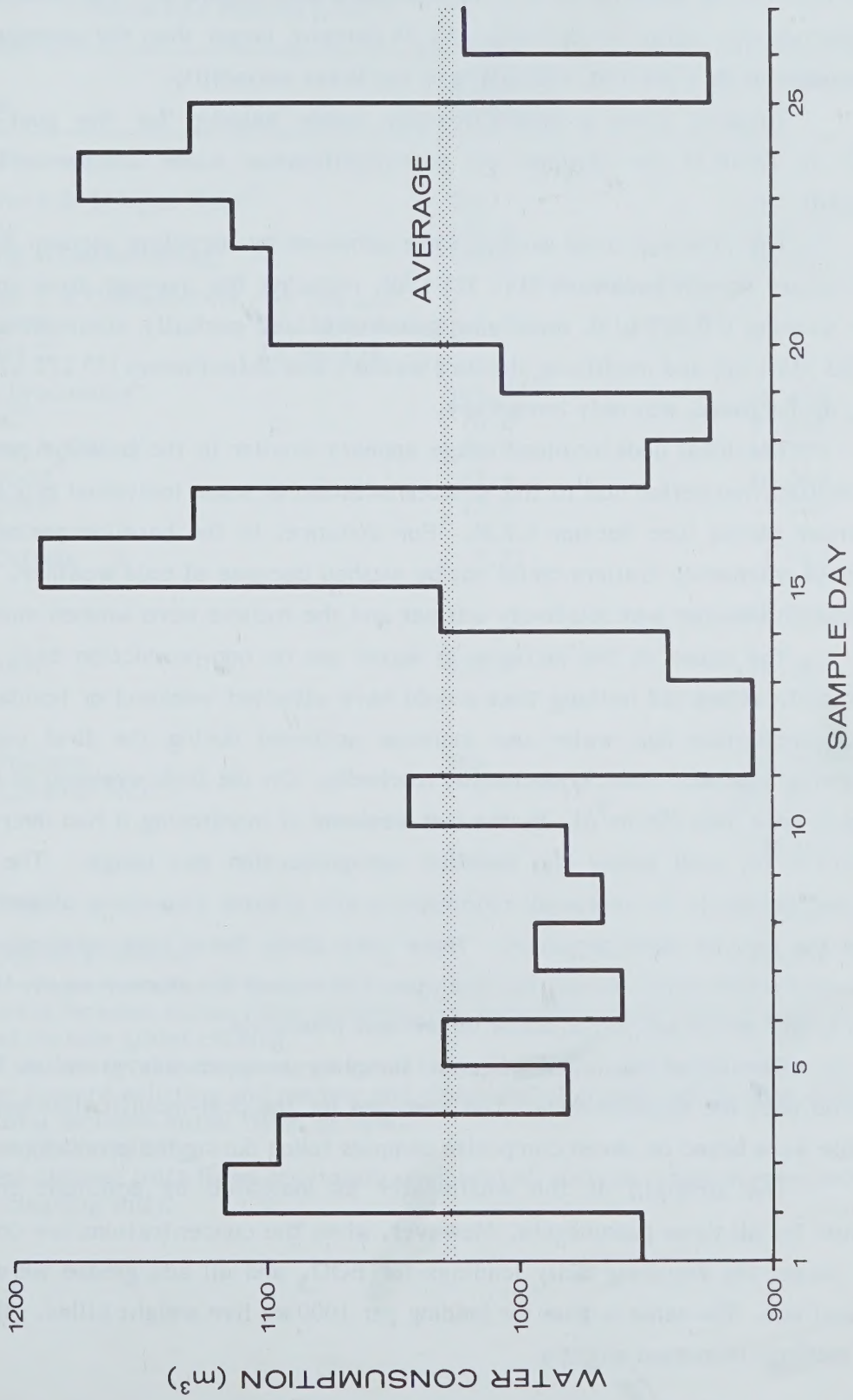


FIGURE 15 POST-MODIFICATION PRODUCTION DAY WATER USE, PINECREST FOODS LTD.

less so than during baseline monitoring (compare with Figure 2). The standard deviation of production-day water use decreased by 34 percent, larger than the average total water use decrease of 28.1 percent, indicative of the lower variability.

Table 14 gives a production-day water balance for the post-modification period. In Table 15 the baseline and post-modification water use per unit process are compared.

The greatest total savings were achieved by recycling vacuum pump effluent to the rotary screen backwash (141 321 L/d), reducing the average time spent on coop trailer washing (79 329 L/d), modifying goosenecks and partially eliminating the sidepan wash (65 354 L/d), and modifying the bird washers and defeatherers (55 278 L/d). This last saving, as discussed, was only temporary.

The total undetermined usage appears smaller in the baseline period than the post-modification period due to the greater inflation of some individual process figures in the earlier period (see Section 4.1.2). For instance, in the baseline period there were many days when coop trailers could not be washed because of cold weather. In the post-modification weather was relatively warmer and the trailers were washed more often.

The cause of the increase in water use on non-production days is uncertain, since modifications did nothing that should have affected weekend or holiday water use. The non-production day water use increase occurred during the first part the post-modification period. Then, it decreased markedly. On the first weekend of monitoring it averaged more than $290 \text{ m}^3/\text{d}$. By the last weekend of monitoring it had decreased to less than $113 \text{ m}^3/\text{d}$, well below the baseline non-production day usage. The decrease is attributed primarily to improved maintenance and greater awareness of water conservation on the part of plant personnel. There were likely fewer taps carelessly left to flow on non-production days. In addition, the plant had moved the stunner supply line so that it was no longer necessary to run water to prevent freeze-up.

Results of the final effluent sampling program are given in Table 16 and compared with the baseline data. The averages for the post-modification period shown in the table were based on seven composite samples taken during the production shift.

The strength of the wastewater as indicated by pollutant concentrations increased for all three parameters. However, when the concentrations are compared with water usage, the resulting daily loadings for BOD_5 and oil and grease were lower after modifications. The same is true for loading per 1000 kg live weight killed. The suspended solids loadings increased slightly.

TABLE 14 PRODUCTION-DAY POST-MODIFICATION WATER USAGE,
PINECREST FOODS LTD.

Unit Process	Flow Rate (L/min)	Daily Consumption (L)
Production Processes		
Gooseneck & Sidepan Wash ^a	200	129 406
Chilling	135.8	101 761
Washing & Defeathering ^b	157.0	70 584
Washer 1 & Defeatherers - 46 906 L/d		
Washer 2 - 11 138 L/d		
Washer 3 - 12 540 L/d		
Giblet Processing ^c	143.3	66 493
Scalder ^d	70.0	53 656
Stunning & Killing	24.0	12 900
Ice Making ^e	18.4	26 549
Sterilizers	15.3	5 224
Foot Recovery	9.1	4 368
Vent Cutting	3.71	1 782
(Sub-total)		472 721
Vacuum System	124.3	119 287
Cleanup		
Coop Trailers	986	89 770
Other Cleanup Shift ^f	-	243 675
(Sub-total)		333 445
Undefined Usage		101 845
PRODUCTION-DAY TOTAL		1 027 300

- a Daily total includes initial fillup of tanks, but does not include addition of ice, also does not include giblet chilling.
- b Second washer total incorporates a small flow to the conveyor table backwash.
- c Includes gizzard splitting and peeling and giblet fluming; does not include chilling.
- d Daily total includes initial fillup of tank.
- e Includes giblet chilling.
- f Excludes cleanup shift flows previously enumerated, such as rotary screen backwash during cleaning shift.

TABLE 15 COMPARISON OF BASELINE AND POST-MODIFICATION UNIT PROCESS WATER USE, PINECREST FOODS LTD.

Unit Process	Daily Consumption (litres)	
	Baseline Period	Post-Modification Period
Production Processes		
Chilling ^a	123 101	101 761
Gooseneck & Sidepan Wash ^a	194 760	129 406
Bird Washers & Defeathering ^b	125 862	70 584 ^c
Giblet Processing ^d	61 621	66 493
Scalding ^e	53 656	53 656
Stunning and Killing	34 586	12 900
Makeup to Feather Flowaway ^f	25 880	0
Ice Making ^g	26 549	26 549
Sterilizers	18 020	5 224
Foot Recovery	15 451	4 368
Vent Cutting	1 782	1 782
Ancillary Uses		
Rotary Screen Backwash	141 321	0
Vacuum System	119 287	119 287
Cleanup		
Coop Trailers	169 099	89 770
Other Cleanup Shift ^h	287 216	243 675
Undefined Usage		
(e.g., thawing, leaks, heating, sanitary)	35 509	101 845
PRODUCTION-DAY TOTAL	1 433 700	1 027 300

- ^a Daily total includes fillup of tanks but does not include addition of ice. Also does not include giblet chilling.
- ^b Second washer total includes a small flow to the conveyor table backwash.
- ^c After completion of the post-modification monitoring, the new systems were redesigned (see Section 4.1.5). The consequent change in water use was not measured.
- ^d Includes gizzard splitting and peeling and giblet fluming; does not include chilling.
- ^e Daily total includes initial fillup of tank.
- ^f Does not include flowaway start-up water.
- ^g Includes giblet chilling.
- ^h Excludes cleanup shift flows previously enumerated, such as rotary screen backwash.

TABLE 16 COMPARISON OF BASELINE AND POST-MODIFICATION EFFLUENT CHARACTERISTICS AND WASTE LOADING, PINECREST FOODS LTD.

	Baseline Period	Post-Modification Period
Concentrations (mg/L)		
BOD ₅	279.2	388.9
Suspended Solids	162.9	257.4
Oil and Grease	51.6	67.1
Daily Loading (kg/d)		
BOD ₅	408.7	399.5
Suspended Solids	238.6	264.4
Oil and Grease	75.3	68.9
Loading per Unit Product (kg/1000 kg LWK)		
BOD ₅	7.96	7.42
Suspended Solids	4.65	4.91
Oil and Grease	1.47	1.28

It had been anticipated that all loadings would decrease to a greater degree. The increased attention to dry cleanup, the new troughing, and the reduced hydraulic loading on the air flotation unit all were expected to contribute to reduced effluent loading. Therefore, after completion of the study, an investigation was undertaken to determine the reasons waste loadings were higher than anticipated.

It was found that the air flotation unit had been operating at relatively low efficiency. The air injection, crucial to the removal of solids and insoluble BOD₅, was operating at less than half the design pressure because air compressor capacity was too low. In the baseline period, when water use was high, the dilute nature of the effluent meant that high efficiency was not necessary from the air flotation unit. However, the higher effluent concentrations with reduced water use required greater efficiency. It was suggested that proper air pressure would result in greatly increased effluent quality.

Pinecrest Foods is assessed a monthly water and sewerage charge by the City of Calgary. In addition, a surcharge may be assessed at a rate based on pollutant concentrations and levied on the water used. Pinecrest is charged \$275.25 for the first 2 273 m³ (500 000 lgal), and \$0.0911 for each additional cubic metre per month (or \$0.41/1000 lgal). Sewer service is 80 percent of the total water bill.

An overstrength surcharge is assessed based on the formula:

$$R = .0112B + .0125S + .0129G$$

where: R = the surcharge rate, in cents per m^3 ,
 B = mg/L BOD₅ over 300 mg/L,
 S = mg/L suspended solids over 300 mg/L,
 G = mg/L oil and grease over 100 mg/L.

The surcharge rate applies for a minimum of three months. It is levied on the total water consumption.

Hypothetical monthly water and sewerage costs were calculated using the baseline and post-modification data. The figures are shown in Table 17.

TABLE 17 COMPARISON OF HYPOTHETICAL MONTHLY WATER AND SEWERAGE COSTS FOR BASELINE AND POST-MODIFICATION MONITORING PERIODS, PINECREST FOODS LTD.

	Baseline Period	Post-Modification Period
Average Monthly Water Use (m^3)	31 043.4	22 898.2
Monthly Water Cost	\$2 896.23	\$2 154.21
Monthly Sewerage Cost	\$2 316.98	\$1 723.36
Surcharge Rate		
mg/L BOD ₅ over 300 mg/L	0	88.9
mg/L Suspended Solids over 300 mg/L	0	0
mg/L Oil and Grease over 100 mg/L	0	0
R ($\text{¢}/m^3$)	0	0.996
Monthly Surcharge	\$ 0.00	\$ 0.00*
Total Monthly Cost (Water + Sewer + Surcharge)	\$5 213.21	\$3 877.57

* The City of Calgary allows a certain "grace" before the surcharge is levied.

The water and sewerage cost reduction is equivalent to a projected \$16 027.68 annually. Total cost of the demonstration project, excluding time invested by study personnel and wastewater sampling and metering costs, was \$5 948.37. Thus, the cost of modifications could be paid back in less than five months.

4.1.7 Summary of the Water and Waste Conservation Program at Pinecrest Foods Ltd.

The modifications at Pinecrest Foods Ltd. resulted in an overall reduction of greater than 25 percent in annual plant water consumption. No significant effect on waste loading was shown.

The program at Pinecrest demonstrated that relatively simple and inexpensive in-process modifications can yield major water use savings in a Canadian poultry plant. It is noteworthy that the greatest savings were achieved in areas that do not involve the direct application of water to the edible product, namely, the rotary screen backwash, coop trailer washing, and evisceration goosenecks and sidepan wash. The modifications were all relatively simple to implement, and required only readily available, inexpensive equipment. Other Canadian plants with above-average water use should have little difficulty making similar modifications.

The general approach was also relatively simple and straightforward. Basically, it involved identifying the patterns of water use at the plant, assessing the efficiency of water use in each unit process, and devising modifications to improve the areas of inefficient water use. After the changes were implemented they were evaluated by plant and inspection staff. Thus, the approach was a "commonsense" one which could be followed at other poultry processing plants.

The results with regard to waste loadings were inconclusive due to problems with the plant's air flotation unit. Although no improvements resulted at Pinecrest due to this site-specific waste treatment problem, other Canadian plants may achieve waste load reductions by applying the principle of minimizing contact between water and waste products.

Although there was no improvement in the quality of effluent discharged from the plant, the reduced effluent volume resulted in major savings in sewerage charges assessed by the municipality. Projected annual water and sewerage cost reductions of over \$16 000 compare favourably with the direct costs of the modifications of about \$6 000.

4.2 Checkerboard Foods Ltd.

4.2.1 Plant Description. The Checkerboard Foods Ltd. poultry processing plant is located in Aurora, Ontario. The plant, built in the 1940's, has been progressively expanded and upgraded with the installation of modern eviscerating and processing equipment and would be considered typical of large Canadian poultry processing operations.

Checkerboard Foods is almost exclusively a broiler processing operation. Of the 7.5 million birds processed at the plant in 1978, more than 97 percent were broilers. The average live weight of birds processed in 1978 was 1.75 kg. The majority of the birds processed originate from Ontario sources, although birds are occasionally imported from the United States when the demand cannot be met locally. Approximately 40 percent of

the total plant production is marketed as whole eviscerated chickens. The remainder is sold as cut-up chicken parts.

The live birds, contained in coops, arrive at the plant by truck. In the receiving area, the coops are off-loaded to a conveyor belt and the birds are hung manually by their feet to shackles suspended from an overhead conveyor line. The coops are washed and disinfected prior to being returned to the truck.

The live birds are stunned electrically and killed automatically. Bleed-out occurs in an enclosed tunnel. The birds are scalded by immersion in an agitated, steam-heated tank at a temperature of approximately 60°C and subsequently defeathered in two picking machines in series. The defeathered birds are washed and hooks removed automatically prior to entering the evisceration room.

In the eviscerating section of the plant, two parallel lines are used. One line is fully automated with mechanical oil sac removal, vent cutting and evisceration equipment. On the second eviscerating line, these operations are performed manually. The birds are inspected, trimmed if necessary, giblets recovered, heads, lungs and kidneys removed and the eviscerated birds given a final wash prior to chilling. Conventional spin-chillers are used for prechilling and final chilling.

At maximum line speed, the plant is capable of slaughtering 6600 birds per hour. Typically, the automatic line is run at full capacity and the manual line at half capacity, resulting in an average processing rate of 5200 birds per hour.

The plant layout is shown in Figure 16. More details regarding the individual unit processes are given during subsequent discussions of water use in the plant.

4.2.2 Baseline Water Use. The Checkerboard Foods Ltd. plant purchases water from the Town of Aurora and consumption is monitored by a 7.5-cm Neptune Trident compound meter. Potable water is used throughout the plant for processing and cleaning. The use of recycled water is limited to transport of feathers in the feather flume and cleaning of coops in the recirculating coop washer.

The baseline data collection phase of the program covered a two-month period from December 5, 1978 to February 3, 1979. During this period, water meters were installed for a number of unit processes, instantaneous flow rates were measured throughout the plant, and daily and shift water use monitored from the town meters. A detailed discussion of the water use associated with each unit process in the plant is provided in subsequent subsections.

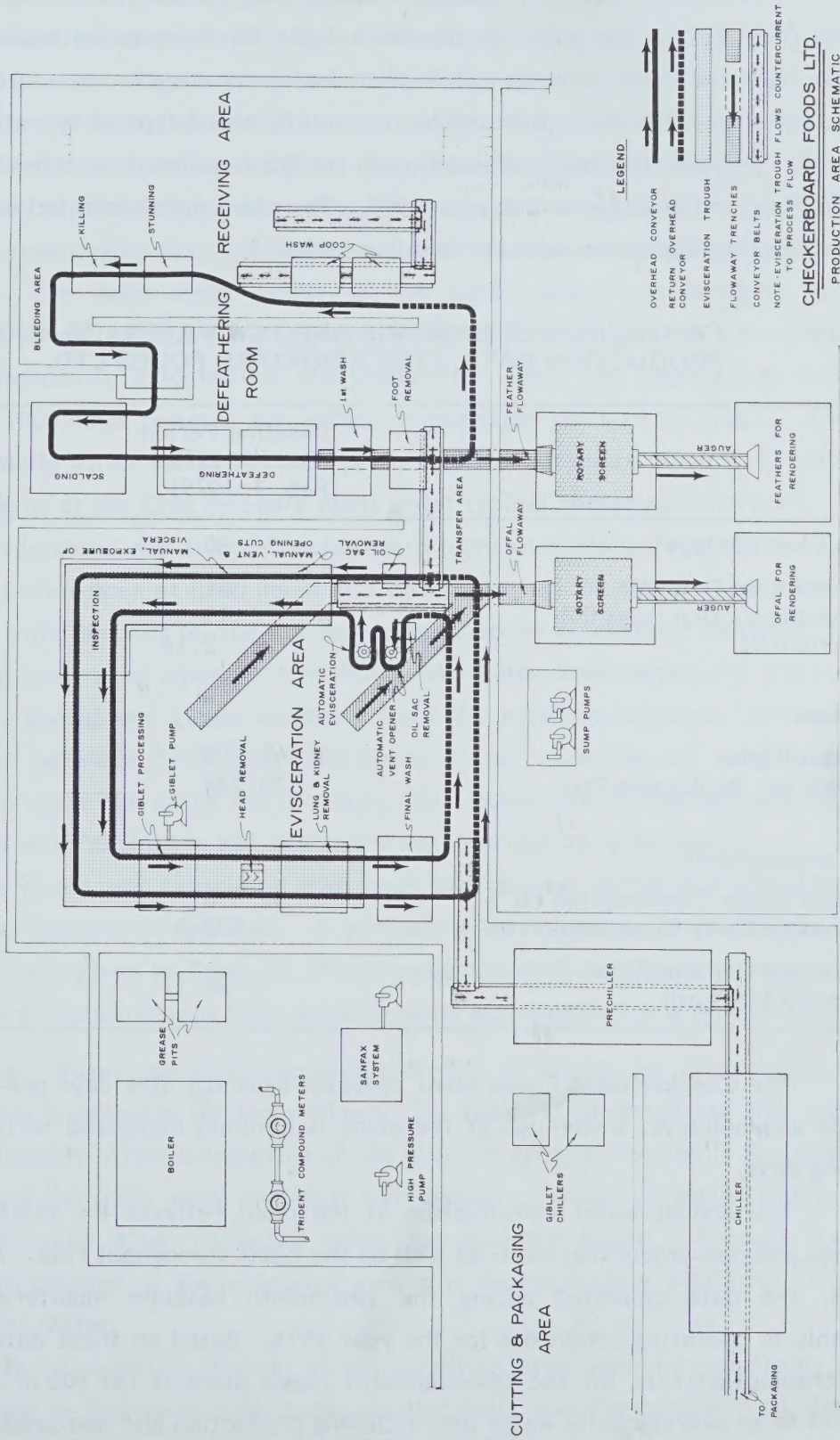


FIGURE 16 CHECKERBOARD FOODS LTD. PRODUCTION AREA SCHEMATIC

A basic objective of the baseline monitoring period was to define the existing water use practices in the plant to provide a basis for comparison with the measured water use after the implementation of in-plant water conservation measures. Therefore, it was essential that the data collected be representative of typical operating conditions. In Table 18, the water use and production data for the baseline data collection period are compared with similar data for the year 1978. The close agreement between these data confirm the suitability of the selected baseline period.

TABLE 18 COMPARISON OF BASELINE AND 1978 WATER USE AND PRODUCTION DATA, CHECKERBOARD FOODS LTD.

	Baseline Period (Dec. 5, 1978 - Feb. 3, 1979)	All 1978
Total Number of Days	60	365
Production Days (P)	41	245
Non-Production Days (N)	19	120
Ratio P/N	2.16	2.04
Production:		
Total Birds	1 241 798	7 503 532
Birds per Production Day	30 288	30 626
Water Consumption:		
Total Water Consumption (m ³)	32 396	196 451
Average Daily Consumption (m ³)	539.9	538.2
Average Consumption Per Bird (L/bird)	26.11	26.20

The Checkerboard Foods plant operates basically five days per week. During weekends and holidays, water use at the plant is minimal compared to consumption on processing days.

The annual water consumption at the plant reflects the relative number of production and non-production days, as well as the plant throughput rate. As indicated in Table 18, the data collected during the two-month baseline monitoring period are comparable to operating conditions for the year 1978. Based on these data, the baseline water consumption rate for the Checkerboard Foods plant is 197 100 m³/year. This is equivalent to an average daily water use, including production and non-production days, of 539.9 m³/d.

Based on daily meter readings taken during the baseline monitoring period, the average daily water use on production days at the Checkerboard plant was 763.1 m^3 . On a production basis, water usage was equivalent to 25.19 L/bird. The water consumed during production days represented almost 95 percent of the annual water use at the plant.

Over the normal range of plant throughput (25 000 to 35 000 birds per day), the daily water use was relatively constant, varying from approximately $680 \text{ m}^3/\text{d}$ to $850 \text{ m}^3/\text{d}$. Representative data collected during the baseline monitoring period are shown in Figure 17. The daily water usage is not significantly correlated to the plant throughput. However, as shown in Figure 18, the water consumption on a production basis (L/bird) is significantly affected by the production rate. An increase in daily plant throughput of 1000 birds reduced the water consumption per bird by 0.68 L. Therefore, comparison of daily water use rather than per bird water use more accurately reflects the water use patterns at the Checkerboard plant under typical operating conditions.

A production day at the Checkerboard plant comprises three shifts. Typically, the 'kill' shift commences at 0700 hours and concludes at 1530 hours. The length of any particular kill shift depends on the number of birds to be processed. Between 1530 and 1730 hours, the processing equipment is shut down, water lines turned off and equipment such as knives, aprons and gloves removed from the evisceration area. Intensive plant cleanup occurs between 1730 and 0230 hours. The 'maintenance' shift works until 0700 hours to prepare the plant for the day's kill. Equipment is checked and lubricated, tanks are filled and the chillers and scalders brought to operating temperatures.

The water uses associated with each unit process during a production day are discussed in subsequent subsections. A production-day water balance for the baseline monitoring period is given in Table 19. These water use data are the average of individual meter readings or instantaneous flow measurements extrapolated to a typical kill shift.

Receiving Area. Water use in the receiving area is primarily for cleaning, although a drinking fountain is provided for the workers. The floors in the receiving area are washed lightly during breaks. After completion of the kill, the area is thoroughly dry cleaned and then washed and sanitized using a central high pressure 'Sanfax' cleaning system. Trucks are washed manually after unloading using low-pressure hoses. Average water use associated with cleanup of the receiving area was approximately 4200 L/d. This figure includes drinking water.

Water use during cleanup of the receiving area varied considerably and was primarily related to the number of trucks washed daily and the condition of the trucks. Daily usage ranged from approximately 3000 L/d to 6900 L/d.

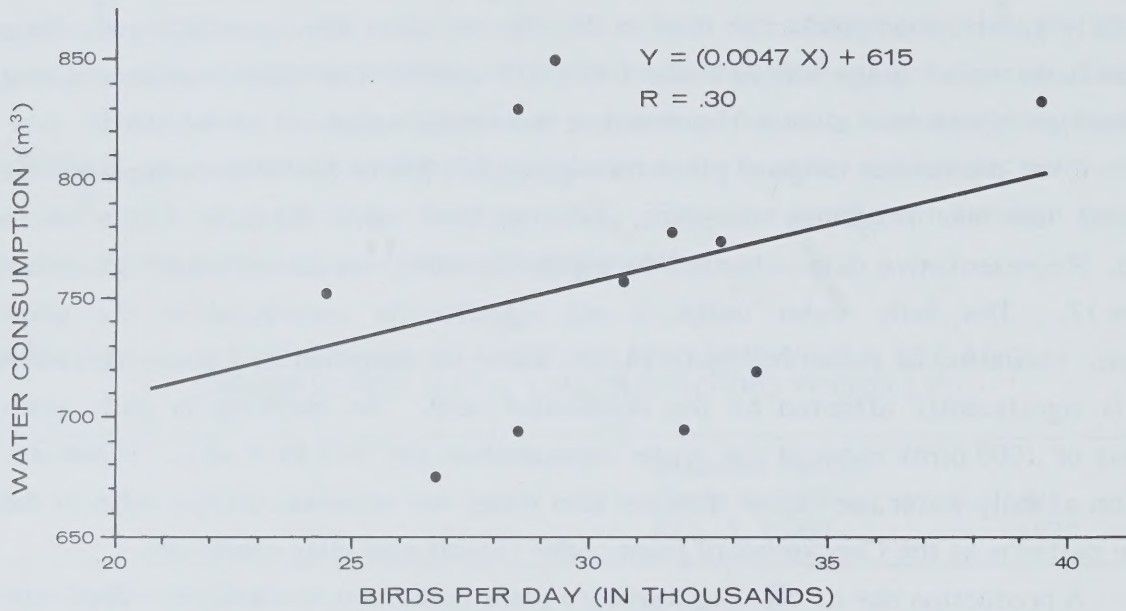


FIGURE 17 CHECKERBOARD FOODS: DAILY WATER USE VERSUS LEVEL OF PRODUCTION

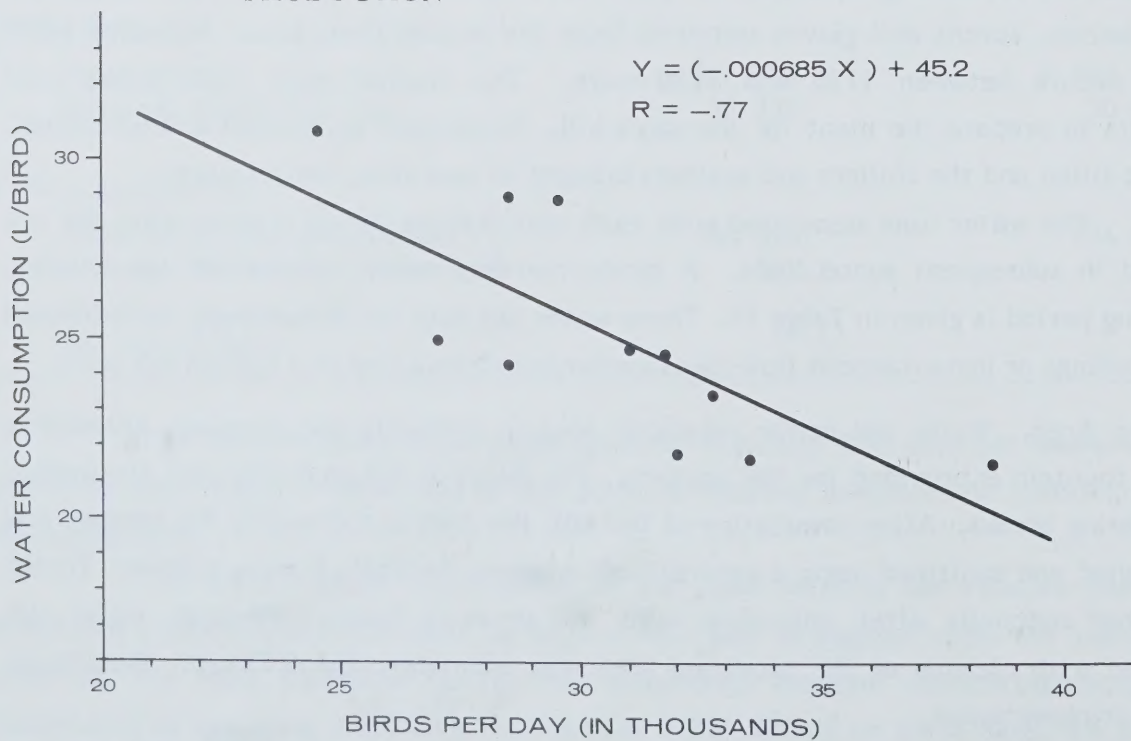


FIGURE 18 CHECKERBOARD FOODS: WATER USE PER BIRD VERSUS LEVEL OF PRODUCTION

TABLE 19 PRODUCTION DAY BASELINE WATER USAGE, CHECKERBOARD FOODS LTD.

Unit Process	Flowrate (L/min)	Daily Consumption (L)
Production Processes		
Coop Wash	63.9	32 600
Stunner	11.3	5 750
Automatic Killer	11.3	5 750
Scalder	52.9	45 000*
Pickers 1)	23.1	11 800
2)	26.1	13 300
Whole Bird Washer	46.7	23 800
Hock Cutter	2.5	1 275
Rehang Conveyor	18.3	9 300
Automatic Evisceration Equipment	35.1	17 860
Side Pan Wash	45.0	25 000
Inspectors' Handwashers	21.8	11 100
Workers' Handwashers	-	10 000
Giblet Pumps & Flumes	15.0	7 650
Gizzard Processing	-	84 400
Final Bird Washer	47.1	24 000
Prechiller	-	65 700*
Chiller	-	58 000*
Giblet Chillers	17.5	8 900
Packing Machines	3.5	1 770
Thawing Frozen Products	-	4 500
(Sub-total)		<u>467 455</u>
Ancillary Uses		
Ice Making	-	30 000
Vacuum Seal Water	-	49 000
Heating	-	8 800
Freezer Floor Defrost	7.1	3 600
Sanitary	-	18 500
(Sub-total)		<u>109 900</u>
Cleanup		
Trucks and Receiving Area	-	4 200
Cleanup Shift	-	141 275
(Sub-total)		<u>145 475</u>
Undefined Uses		
(e.g., miscellaneous leaks, cleanup during kill shift)	-	<u>40 260</u>
PRODUCTION-DAY TOTAL	-	<u>763 090</u>

* Daily Consumption includes initial filling of tank.

It is noteworthy that prior to the intensive flow monitoring program, the water fountain ran continuously during the kill shift at a rate of approximately 5 L/min. When a meter was installed on this line to measure receiving area water use, the drinking fountain was shut off and used only as required. Thus, the simple installation of a water meter resulted in a daily water saving of approximately 2400 L, equivalent to almost 50 percent of the water used for cleaning the receiving area. The excessive water use associated with the continuous operation of the drinking fountain is not included in the baseline water use figure for the receiving area.

Coop wash. The major water-consuming operation in the receiving area is the cleaning and sanitizing of empty coops. The coops are washed in a continuous two-stage recirculating shower. Potable makeup water is added continuously to each stage of the unit, at an average rate of about 64 L/min. Screened washwater is recirculated from a sump in each stage through drilled pipes. Sodium hypochlorite can be added to the second stage of the washer as a disinfectant. The coop washer contributed 32 600 L/d to the total plant water usage.

Killing and bleeding. Potable water is added as makeup to the stunner at a rate of approximately 11.3 L/min. An additional 11.3 L/min is applied to the automatic killer to lubricate and rinse collected blood from the guide bars and cutting blades. There is no water usage associated with the bleeding operation, except during plant cleanup. The collected blood is removed from the confinement area by a vacuum system at the end of the kill shift and sent, along with feathers and offal, to an independent renderer. Thus, total production water use in the killing area was approximately 11 500 L/d.

Scalding. The 6500 L scald tank is filled during the morning shift at about 0400 hours and heated with steam to ensure that a temperature of 60°C is attained by the start of the kill shift. During the production shift, makeup water is added to the scalding tank continuously at an average rate of 52.9 L/min to maintain an overflow. The makeup water is applied, by means of two showerheads and a spray nozzle, to the overhead conveyor to wash and lubricate the conveyor wheels. Overflow from the scalding tank enters the feather flume to assist in transporting feathers away from the picking operation.

During the cleanup shift, the scalding tank is emptied, refilled and agitated prior to dumping to remove any settled solids. The tank is then washed down with hoses and sanitized. Total daily water usage associated with scalding, including the twice daily filling of the tank, was estimated at 45 000 L/d.

Defeathering. The revolving 'fingers' in the two pickers are lubricated by the addition of potable water through drilled pipes within the machines. Water usage in the first and second pickers averaged 23.1 L/min and 26.1 L/min, respectively, during the baseline data collection period. This is equivalent to a total of approximately 25 100 L/d. This water assists in washing the feathers from the birds to the in-ground feather trough beneath the picking machines where they are transported by recirculated water to a trommel screen. The feathers are recovered and transferred by a screw conveyor to a truck for transporting to rendering. Feather flume water, combined with screened eviscerating trough water, is recirculated to the feather flume. Excess water overflows the recirculation sump to the effluent sewer.

Whole bird washer. Blood and loose feathers are washed from the birds as they exit the pickers by six low-pressure domestic showerheads. Total water usage in this operation averaged approximately 46.7 L/min, equivalent to 23 800 L/d. The wash water eventually enters the feather flume.

Hock cutter. Legs are removed from the birds by an automatic hock cutter. The birds fall to a conveyor which transfers them into the eviscerating room rehang station. The legs are automatically removed from the shackles, transferred to a conveyor and dumped into the offal flume to be recovered, along with viscera, for rendering. During the baseline data collection phase, no water was used in this operation. However, prior to completion of the study, a spray nozzle was added to lubricate the leg chute and facilitate movement of the legs to the offal flume. Although water consumption in this operation was minimal (approximately 2.5 L/min) this volume has been added to the baseline water consumption figure.

Rehang station. The rehang conveyors are washed continuously by eight low-volume spray nozzles utilizing a total of approximately 18.3 L/min, or 9300 L/d.

Automatic evisceration equipment. The automatic evisceration equipment, used for oil sac removal, vent opening and viscera removal, is washed continuously to prevent any cross-contamination. Wash water is applied through spray nozzles to all surfaces that contact the birds. Total water usage during these operations averaged approximately 35.1 L/min, or 17 860 L/d.

Eviscerating line. A number of sources contribute to the total flow in the eviscerating trough. These were difficult to quantify individually because of the number of potable water supply lines feeding the trough.

The eviscerating trough is of conventional design. A number of stainless steel sections are welded together in a U-shape. Work stations are located on both sides of the trough. During most of the in-plant study period, four inspection stations were used; however, a fifth station was added toward the end of the study. Ancillary equipment along the trough is provided for sorting, washing and transfer of hearts and livers, cleaning and transfer of gizzards, lung and kidney removal and removal of heads and tracheae.

Both sides of the eviscerating trough are washed continuously by a system of drilled pipes running the length of the trough. Fourteen hand-wash stations are located along the trough for the workers. Each of these stations has a flexible plastic hose equipped with a hand-operated valve. The workers use these stations to wash their hands, equipment and plastic aprons. The frequency of usage varies considerably between workers. In addition to these wash stations, two goosenecks were located along the eviscerating trough. These faucets ran continuously at a rate of between 1.4 L/min and 2.6 L/min, depending on the water pressure and valve setting.

The inspection tables were washed continuously by a system similar to that used for the side pan wash. In addition, each inspection station was equipped with a gooseneck which ran continuously at a rate of between 2.1 L/min and 13.6 L/min so that the inspector could wash his hands as frequently as necessary during the inspection process. These handwashers contributed approximately 11 100 L/d to the total plant water usage.

After inspection, hearts, livers and gizzards are separated from inedible viscera. The hearts and livers are flumed with potable water to a piston pump which transfers them directly to chillers. Water usage in this operation averaged 7650 L/d during the baseline survey.

Gizzard processing involves splitting, peeling and washing by specially designed equipment using considerable quantities of water. Average water consumption associated with these processes was approximately 84 400 L/d. The clean gizzards are pumped in a water stream to a separate gizzard chiller.

Final bird wash. The eviscerated birds received a final wash in a shower cabinet equipped with nine low-pressure domestic showerheads. Water usage in this process averaged 47.1 L/min, or 24 000 L/d. The wash water combined with the flow in the eviscerating trough to aid in transporting viscera from the eviscerating room to a screw conveyor which recovers the gross solids for rendering.

Chilling. The washed, eviscerated birds are transferred from the overhead conveyor initially to a prechill tank and then to a final chill tank to rapidly reduce the temperature of the carcass. Water usage in these chillers varies considerably depending on the temperature and condition of the birds. A 5-cm pipe is provided to fill each chiller and separate 2.5-cm lines are used to supply makeup water. In some cases, both lines are opened to maintain the desired temperature and flush accumulated blood and grease from the chillers.

During the baseline study period, average water usage in the prechiller was 65 700 L, including the 11 650 L required for initial filling of the tank. This is equivalent to an average per-bird usage of 1.54 L. The daily usage ranged from 49 000 L to 70 910 L. However, the instantaneous makeup rate to the prechiller varied over a considerably wider range, from 12.3 L/min to 158.9 L/min. The fresh water feed rate was continuously adjusted depending on the general appearance of the water in the tank.

A similar procedure was observed for the final chiller. Average water consumption was 58 000 L/d, equivalent to approximately 1.28 L/bird, including the 19 000 L required for initial filling. The range of daily usage was from 53 000 L to 65 000 L; however, the instantaneous makeup rate varied from 17.8 L/min to 82.9 L/min.

Giblet chillers. Two chillers, one for hearts and livers and one for gizzards, are operated in a manner similar to that used for the bird chillers. Water use varied considerably during the day depending on the valve setting; however, the average total usage in the two chillers was approximately 17.5 L/min, equivalent to a daily consumption of 8900 L.

Cut-up and packaging. These operations use little water. The only continuous use of water is for cooling two vacuum packaging machines. This water is recirculated from the first machine to the second machine at a rate equivalent to 3.5 L/min.

Thawing of frozen poultry products. The largest intermittent water usage in the plant is associated with thawing of frozen poultry for subsequent processing. Whole birds or parts are placed in stainless steel tanks and a continuous flow of water is used to thaw them. The amount of water used during any particular day will depend on the quantity of frozen products thawed. The average daily usage for thawing was approximately 4500 L; however, this varied considerably. On days when a large supply of live birds were available to meet the demand for cut-up products, no thawing was done. On one occasion, more than 150 000 L was recorded for thawing water on one day.

Production-related water usage. As shown in Table 19, the total water used in the production-related processes described above was $467.5 \text{ m}^3/\text{d}$ during the baseline monitoring period. On a production basis, this is equivalent to 15.43 L/bird and represents approximately 61 percent of the total production-day water usage.

Ancillary usage. The water associated with various plant utilities such as ice-making, vacuum pump seal water, heating and sanitary usage was estimated and is given in Table 19. Included in this category is a daily usage of 3600 L of hot water (7.1 L/min) during the kill shift to prevent ice formation on the floor in the packaging area of the freezer. The overall daily water use associated with these operations is approximately 109 900 L, or 14.4 percent of the production day total usage. The largest single contributor to the total is the seal water used in the vacuum pump.

Cleanup operations. Cleanup operations represent the single major water use in the plant. Intensive plant cleanup is conducted after completion of the production shift. Low-pressure, open-ended hoses were used to remove gross solids to the evisceration or feather flowaways. Floors, tanks and processing equipment were then cleaned and sanitized. In addition to the intensive cleanup, cursory cleaning, of the eviscerating room in particular, was conducted during breaks in the production-shift. The plant did not enforce a strict policy of dry cleanup prior to washdown of the plant. The amount of dry cleanup depended on the normal practice of the particular operator.

The water use associated with the intensive plant cleanup was estimated based on water meter readings taken prior to commencement and after completion of the shift. These readings were corrected for background uses occurring at the same time. The quantity of water associated with the cleanup shift was estimated to be approximately 141 275 L/d, equivalent to 18.5 percent of the daily total usage. The cleanup shift water usage was relatively constant and independent of the daily production rate; however, the instantaneous or hourly usage varied considerably depending on the actual operations being conducted.

In addition to the major cleanup usage associated with the cleanup shift, cleaning water was used in the receiving area (4200 L/d average) and during production shift. No estimate could be made of the amount of water used in cleanup during the kill shift and this volume is included in Table 19 as undefined.

During weekends and holidays, the only water used in the plant is associated with such utilities as plant heating, refrigeration and ice-making. Numerous leaks were

also evident in the plant piping system which contributed to the total water consumption during non-production days. Based on the total water usage during the baseline study period, the production day water use and the relative number of production and non-production days, the non-production day water use was estimated as $58.4 \text{ m}^3/\text{d}$.

Based on the two-month baseline monitoring period considered to be representative of normal operating conditions at the Checkerboard Foods Ltd. poultry processing plant, the following data were selected to define the water use practices at the plant prior to the implementation of in-plant conservation measures:

Water Use:

Average Production Day Usage	763.1 m^3
Average Non-Production Day Usage	58.4 m^3
Equivalent Annual Usage	197 100 m^3

Production-Based Use:

Total	26.11 L/bird
Production Day	25.19 L/bird

4.2.3 Baseline Waste Loads. Process effluents, with the exception of flowaway water from the evisceration and feather flumes, are discharged through a grease trap to a biological pretreatment system. The flowaway streams are screened to recover offal and feathers and then discharged directly to the pretreatment plant.

The combined process effluent receives primary clarification to remove residual floatable grease and settleable solids. The effluent is then biologically-treated in an extended aeration plant utilizing floating surface aerators prior to secondary clarification. The treated effluent is discharged to the municipal sewer system.

Effluent sampling was conducted prior to primary clarification at the pretreatment plant. Composite samples were taken of the process effluent resulting from the kill (production) shift and from the cleanup/maintenance (non-production) shifts. The results are given in Tables 20 and 21, respectively.

Total process effluent flow through the treatment plant was monitored by means of a Parshall flume. However, early in the baseline monitoring period, the level sensor froze and little further data could be obtained from this source. Therefore, the daily process effluent loadings were calculated based on estimates of the process effluent flow from each shift. The production-based (per bird) loadings were also estimated. The total effluent loadings during the baseline monitoring period are summarized in Table 22.

TABLE 20 BASELINE PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, CHECKERBOARD FOODS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
Jan. 8/79	1 020	460	118	376
Jan. 9/79	1 070	580	127	231
Jan. 10/79	1 050	670	108	496
Jan. 11/79	855	660	45.5	405
Jan. 12/79	933	610	118	281
Jan. 15/79	1 240	620	91.7	624
Jan. 16/79	1 020	800	105	327
Jan. 17/79	-	670	68.9	336
Jan. 18/79	849	530	82.3	144
Jan. 19/79	1 030	210	-	-
Jan. 22/79	737	570	-	-
Jan. 23/79	925	445	120	245
Jan. 24/79	857	315	52.1	119
Average	966	549	94.2	326

TABLE 21 BASELINE NON-PRODUCTION SHIFT* PROCESS EFFLUENT CHARACTERISTICS, CHECKERBOARD FOODS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
Jan. 3/79	575	400	71.4	95.6
Jan. 17/79	-	250	82.3	70.1
Jan. 18/79	1 120	480	79.5	15.2
Jan. 19/79	498	270	70.0	49.3
Jan. 23/79	352	175	20.7	74.4
Jan. 24/79	340	115	25.2	131
Average	577	282	61.6	72.6

* The non-production shift represents the combined cleanup and maintenance shifts.

TABLE 22 BASELINE PROCESS EFFLUENT WASTE LOAD, CHECKERBOARD FOODS LTD.

	Parameter				
	BOD ₅	Suspended Solids	Total Kjeldahl Nitrogen	Oil and Grease	
<u>Production Shift:</u>					
Average Concentration (mg/L)	966	549	94.2	326	
Loading (kg)	461	262	45	155	
<u>Non-Production Shift:</u>					
Average Concentration (mg/L)	577	282	61.6	72.6	
Loading (kg)	165	81	18	21	
<u>Total Production Day:</u>					
Concentration (mg/L)*	820	448	82.1	230	
Daily Loading (kg/d)	626	343	63	176	
Production-Based Loading (kg/1000 birds)	20.7	11.3	2.1	5.8	
(kg/1000 kg LWK)	11.8	6.5	1.2	3.3	

* The average effluent concentration for a production day was calculated from the total daily waste loading and the average production day water use (763.1 m³/d).

The process effluent BOD₅ loading is within the range typically reported in the literature (see Appendix A).

In addition to the total process effluent samplings, selected streams in the processing plant were sampled and analyzed. The results of these limited samples are summarized in Table 23. The individual stream data cannot be compared directly with the total process effluent sampling data as considerable quantities of grease and solids are removed by the grease trap. However, these data indicate that the offal flume, feather flume and prechiller overflow represent large contributions to the total process effluent loading. The feather flume, in particular, is a concentrated waste stream by the end of the production shift because of continuous recycling and contaminant accumulation. Similarly, grease accumulation is evident in the prechiller effluent during the course of the kill shift.

Some operational problems were evident in the biological pretreatment system during the baseline monitoring period. The most serious problem was filamentous microorganisms which settled poorly and contributed to high suspended solids concentrations in the treated effluent, as shown in Table 24. Poor flow distribution was evident in the final clarifier. Problems were also frequently encountered with the surface aerators during low temperature operation. Despite these problems, the treatment plant functioned well biologically, as indicated by the relatively low effluent filtered BOD₅ concentration. As indicated in Table 24, the average discharge quality was within the Town of Aurora bylaw limits. However, on several occasions, the total BOD₅ and suspended solids concentrations exceeded these limits due to the poor settleability of the biological solids in the final clarifier.

4.2.4 Plant Attitudes. The ultimate success of any water and waste management program depends to a very large extent on the attitudes of the personnel at the plant. This encompasses plant management, production personnel and cleanup staff, as well as Agriculture Canada inspection staff.

Management personnel at the Checkerboard plant were very receptive to the goals of the demonstration program. They were well aware of the escalating costs associated with purchasing water from the Town of Aurora and discharging process effluents to the municipal water pollution control plant. The plant had not instituted a comprehensive water and waste management program per se and no one at the plant was directly responsible for monitoring, implementing and enforcing good water use practices. However, plant management had successfully implemented various modifications in the

TABLE 23 BASELINE CHARACTERISTICS OF INDIVIDUAL PROCESS STREAMS,
CHECKERBOARD FOODS LTD.

	Average Concentration (mg/L)			Estimated Daily Loading (kg/d)		
	BOD ₅	Suspended Solids	Oil and Grease	BOD ₅	Suspended Solids	Oil and Grease
Coop Wash Overflow	430	740	18.4	14.0	24.1	0.6
Offal Flume	700	880	810	59.9	75.0	69.0
Feather Flume	2 500	1 950	118	122.4	95.5	5.8
Prechiller Overflow	979	630	1 210	52.9	34.1	65.4
Chiller Overflow	609	156	91.8	23.8	6.1	3.6
Giblet Chiller Overflow	568	200	-	5.1	1.8	-

TABLE 24 BASELINE TREATED EFFLUENT QUALITY, CHECKERBOARD FOODS LTD.

Parameter	Average Concentration (mg/L)	Town of Aurora Bylaw Limits (mg/L)
Total BOD ₅	408	500
Filtered BOD ₅	15	-
Suspended Solids	430	600
Oil and Grease	29.8	100
Total Kjeldahl Nitrogen	96.6	-

plant to eliminate some of the wasteful water use practices commonly reported in surveys of the poultry processing industry. One of the most obvious steps taken to reduce water consumption was the substitution of hoses equipped with hand-operated valves for the conventional gooseneck handwashers at many of the evisceration line work stations. Most of the remaining goosenecks, with the exception of those used by inspection personnel, were equipped with hand-operated demand valves. In addition, during the baseline monitoring period it was noted that hoses were regularly turned off when not in use and that most production-related water sources were turned off during breaks and immediately after completion of the kill shift. The relatively low water consumption measured during the baseline study period (approximately 26 L/bird compared with a higher industry average; see Appendix A) indicates that plant personnel had already been fairly successful in controlling excessive water use.

Agriculture Canada inspection staff, particularly the veterinarian-in-charge, were also receptive to the goals of the program, with the provision that product quality was not in any way compromised as a result of the in-plant modifications. The veterinarian-in-charge was willing to evaluate any modification that was deemed to be appropriate. However, at the onset of the study, the opinion was expressed that reductions in water usage to less than about 23 to 27 L/bird were difficult to accomplish without affecting product quality unless substantial capital investments in new equipment, such as dry offal transport systems, were made.

4.2.5 Modifications. During the baseline monitoring period, a number of operations in the plant were identified as being inefficient in terms of water usage or as being

excessive contributors to the plant waste load. The in-plant modifications and the individual effects are discussed in detail below.

Reuse of Vacuum Pump Seal Water in Coop Washer. Potable water had been supplied as continuous makeup to the two-stage coop washer in the receiving area. At the same time, seal water for the vacuum pump was used on a once-through basis and discharged to the floor drains.

As the coop washer and the vacuum pump used similar quantities of water and the vacuum seal water was essentially clean, a recycle system was installed to return vacuum pump seal water as makeup to the coop washer. An 82-L polyethylene tank was used to collect vacuum seal water and a small centrifugal pump used to recycle the water to the coop washer. A Flygt level-controlled on-off switch was also installed to ensure that the centrifugal pump was not left operating after the vacuum pump was shut off. The recycle system is shown in Figure 19.

The cost of these modifications was:

Materials

Polyethylene Tank	\$32.32
Atlas-Monarch BSE-33 pump	\$194.77
Flygt Switch	\$67.41
Korotron Braided Tubing	\$240.00
Misc. Pipe Fittings	\$ 127.05
Misc. Electrical Accessories	\$ 7.02
Sub-total	\$ 668.57

<u>Tax</u>	\$ 111.18
Sub-total	\$ 779.75

Labour

Electrical Installation	\$ 60.16
Plumbing, 20 hours @ \$10/hour	\$ 200.00
Total	\$1 039.91

Although adequate water was available from the vacuum pump (49 000 L/d) to provide all of the makeup requirements of the coop washer (32 600 L/d), the Checkerboard plant had taken delivery of a new vacuum pump to be used in conjunction with new automatic lung and kidney removal equipment. The new vacuum pump would be installed to reuse a fraction of the seal water. Furthermore, as sodium hypochlorite is used as a

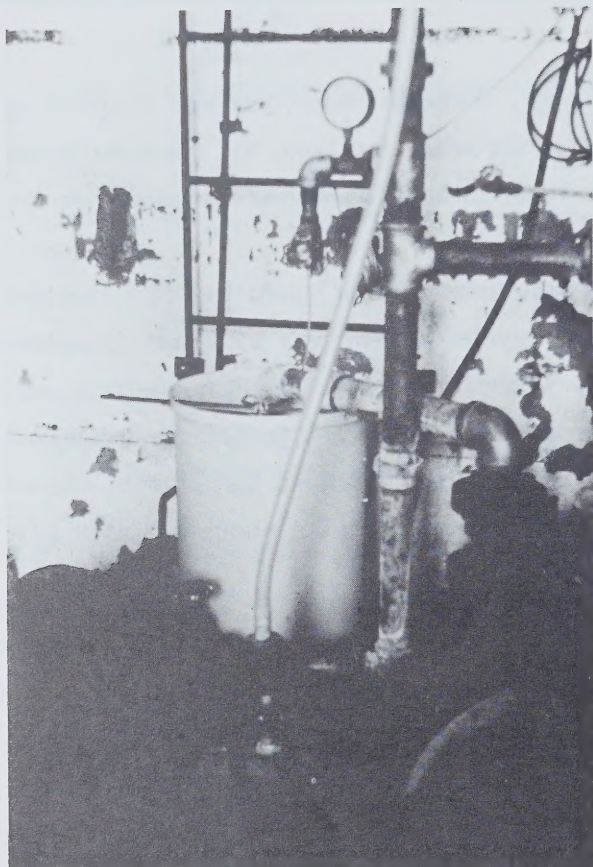


FIGURE 19 RECYCLE SYSTEM FOR
VACUUM PUMP SEAL
WATER

Photo shows collection tank on
vacuum pump discharge and
centrifugal pump feeding cap
wash system.

disinfectant in the coop wash system, use of recycled water in both stages would be expensive in terms of disinfectant costs relative to the costs associated with the original internal recirculation mode. Therefore, the recycle system for the coop washer was designed to supply vacuum pump seal water only to the first stage of the coop wash system. Fresh water makeup was maintained to the second stage.

Water use in the coop wash was reduced by approximately 50 percent by this modification to a level equivalent to 16 600 L/d. This is equivalent to an annual water saving of 3920 m³, which represents an annual reduction in water and sewer costs of about \$570. Thus, the payback period on the modifications would be approximately two years,

neglecting maintenance and depreciation costs. However, had the system been designed to recycle all vacuum seal water and eliminate fresh water makeup to the coop washer, the annual water saving would approximately doubled for a relatively small increase in equipment costs to provide a larger pump.

Receiving area drinking fountain. A drinking fountain was provided for the workers in the receiving area. The fountain ran continuously prior to the start of the intensive baseline monitoring period at a rate of approximately 5 L/min, representing a total daily flow of about 2400 L/d.

Although the total flow from the drinking fountain in the receiving area is miniscule, less than 0.5 percent of the daily usage during the production day, and is not included in the baseline water use figure because it was shut off prior to intensive flow metering, it is an interesting example of the effect of water management programs on plant personnel. At the start of the intensive flow monitoring period, a water meter was installed in the receiving area to record water usage associated with cleanup operations and truck washings. The drinking fountain was on the same pipe and located in close proximity to the water meter. Immediately after installation of this meter, the fountain was shut off and used for the rest of the study period on a demand basis.

No cost analysis was made of this modification because the meter was not intended specifically to eliminate this wastage. More cost-effective methods, such as the installation of a press-to-open valve, would have accomplished the same goal. In addition, the annual saving in water and sewer costs represents only about \$85 based on the 1979 Town of Aurora water and sewer rates. However, the response of plant personnel to the knowledge that water use was being monitored is indicative of the psychological effect of water conservation programs on water use practices. Other examples of closer personal control of water use were evident in the plant after all plant personnel were informed of the goals of the study at the end of the baseline monitoring period.

Modifications to the blood tunnel. Because of the gradual increase in production rate at the Checkerboard plant, the travel time from the killer to the end of the blood tunnel is relatively short. Additional bleeding time is available from the end of the blood tunnel to the front end of the scalding. As a result, considerable quantities of blood collect on the floor outside the curbed tunnel (Figure 20). Some of this coagulated blood was washed continuously into the feather flume during production hours because of the proximity of the scalding overflow and flume water recycle pipe. In addition, although cleanup



FIGURE 20 BLOOD ACCUMULATION ON FLOOR OUTSIDE CURBED BLEED TUNNEL

personnel were supposed to collect this blood along with that inside the blood tunnel, it was frequently shovelled into the feather flume at the end of the production shift. All of these factors contributed to an excessive quantity of blood in the process effluent.

Management at the Checkerboard plant was aware of the problems in the area of the blood tunnel and planned to increase the bleed time by increasing the length of the overhead conveyor. However, such a modification is expensive and was outside the scope of the demonstration project. Therefore, an alternative solution to temporarily reduce blood losses to the sewer was sought.

The installation of troughing between the end of the blood tunnel and the scalding was proposed to collect the additional blood and return it to the blood tunnel. As a suitable section of stainless steel eviscerating trough was available, this represented a low-cost modification. However, production personnel indicated that troughing in this area would interfere with the adjustment of the speed control for the overhead conveyor and constitute additional equipment for daily cleanup. Therefore, new curbing was installed to contain the blood and prevent it from being flushed continuously into the feather flume.

This modification cost:

Materials, 5 bags cement @ \$2.95	\$ 14.75
Labour, 10 hours @ \$10/hour	<u>\$100.00</u>
Total	\$114.75

Although a considerable quantity of blood was collected within the curbed area, no reduction in the total plant effluent BOD₅ was recorded (Section 4.2.7). In addition, sampling of feather flume water after installation of the new curbing did not indicate a reduction in waste strength. As the birds are still bleeding when they enter the scalders, it is possible that the BOD content of the scalders overflow is sufficiently high to mask the effect of any reduction in blood losses from the floor area. Furthermore, it is possible that the new curbing did not deter cleanup personnel from shovelling the additional blood into the feather flume. Although this was never observed by study personnel, excessively high concentrations of blood were noted occasionally in process effluent samples taken during the cleanup shift. Regardless of the cause, no reduction in waste load could be quantified as a result of the modification.

Defeathering machines. The two defeathering machines were equipped with drilled pipes supplying potable water to lubricate the picker fingers and flush feathers from the birds to the feather flume. As drilled pipes are commonly cited as an inefficient means of supplying water, this was considered as an area of potential improvement.

Alternate holes in the internal water pipes were fitted with fulljet spray nozzles (Spraying Systems No. 1/8HH-48SQ). The remaining holes were plugged with sheet metal screws. It was felt that the improved distribution of water resulting from the spray nozzles would compensate for the reduced water volume applied to the pickers.

The cost of this modification was:

Materials

12 Fulljet Nozzles @ \$2.30	\$ 27.60
12 Split Eyelets @ \$2.97	<u>\$ 35.64</u>
	\$ 63.24
<u>Tax</u>	<u>\$ 10.52</u>
Sub-total	\$ 73.76

Labour

3 hours @ \$10.00/hour	<u>\$ 30.00</u>
Total	\$103.76

The modifications to the defeathering equipment were unsuccessful. The first birds processed after modification at the start of the kill shift began to show black marks. These marks were traced to deterioration of the rubber fingers in the pickers. Despite the improved distribution of water in the equipment, the volume of water was not adequate to immediately lubricate all of the picker fingers.

It appears that there is a minimum water requirement associated with proper defeathering machine operation. Although the baseline usage of approximately 24 L/min may be excessive, the installation of spray nozzles and metal screws reducing the flow to about 12 L/min resulted in an inadequate supply of water to the equipment. A more suitable method of optimizing water use in such equipment would be a gradual reduction in flow rather than the one-step reduction attempted during this study.

Whole bird washer. Blood and loose feathers were washed from the birds after defeathering by six low-pressure, high-volume domestic showerheads (Figure 21).

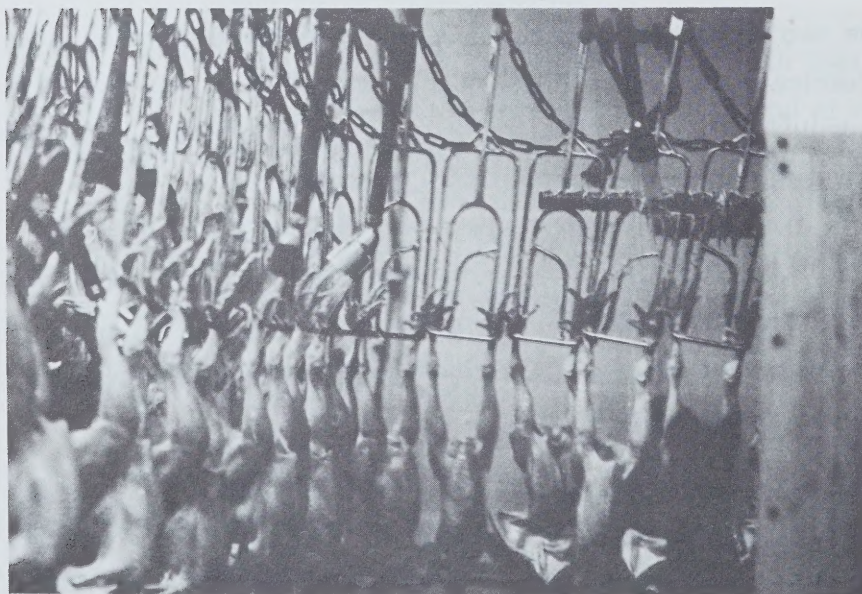


FIGURE 21 ORIGINAL WHOLE BIRD WASHER,
CHECKERBOARD FOODS LTD.

Photo shows alignment of domestic
showerheads.

The whole bird washer was modified based on the design developed by Whitehead *et al* (6). The washer, illustrated in Figure 22, consisted of two parallel manifolds each containing five spray nozzles. The manifold was aligned at 45° to the vertical and the spray nozzles installed in such a way that each successive nozzle sprayed lower on the bird as it travelled through the manifold on the overhead conveyor.

Some experimentation was conducted with different types of nozzles. Both Veejet (Spray Systems H 1/4 U-5010) and Flatjet (Spray Systems P-5010) were used in various combinations, and ultimately three Veejet and two Flatjet nozzles on each manifold were selected.

The cost of this modification was:

Materials

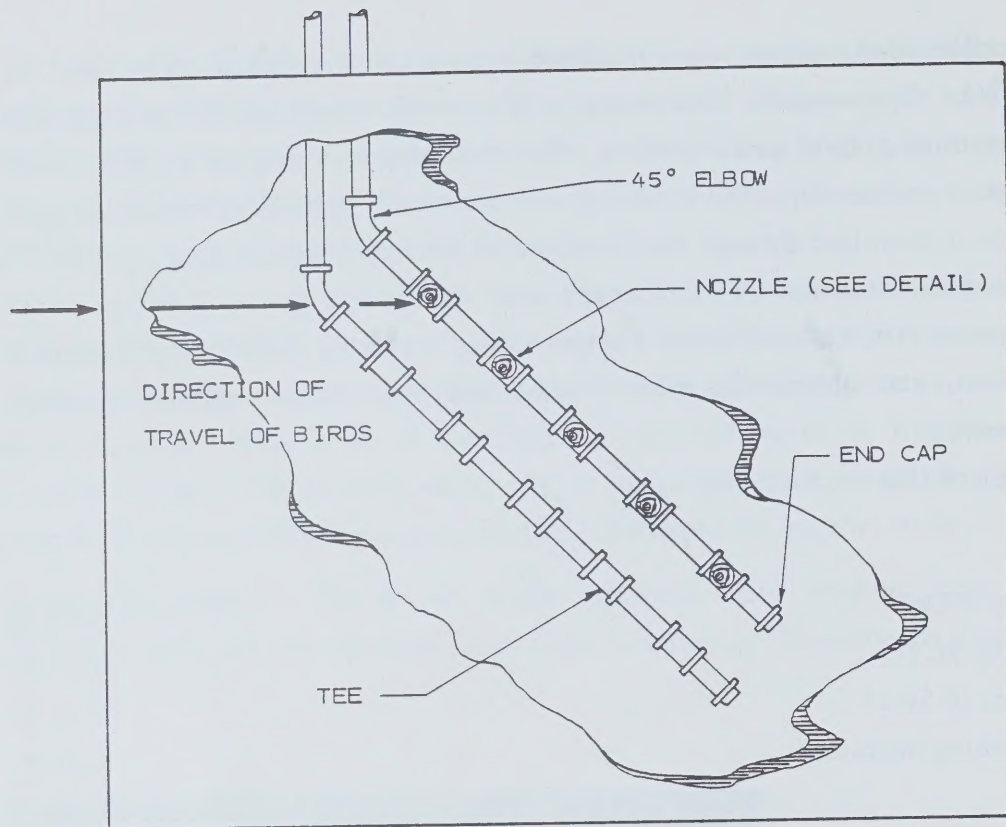
8 Flatjet Nozzles @ \$5.42	\$ 43.36
10 Veejet Nozzles @ \$1.21	\$ 12.10
10 Adjustable Joints @ \$4.13	\$ 41.30
Miscellaneous Plumbing Supplies	<u>\$ 31.91</u>
	\$128.67
<u>Tax</u>	<u>\$ 21.40</u>
Sub-total	\$150.07

Labour

10 hours @ \$10.00/hour	<u>\$100.00</u>
Total	\$250.07

During production hours when water usage was at a maximum in the plant, the water pressure was not consistent enough to produce a good spray pattern from the nozzles. The redesigned manifold was as effective as the original showerheads when the line pressure was greater than about 175 to 200 kPa, and the new system used about 50 percent less water (22.7 L/min compared to 46.7 L/min with the old system). However, when the line pressure dropped, the spray nozzles did not adequately remove residual feathers and blood from the birds. As the original system did not rely on high-pressure, low-volume application of water, it was considerably more effective than the redesigned system during periods of low water pressure at the plant.

Low water pressure was a problem throughout the plant during the study. In addition, the plant has had problems with high iron content in the water. This



SIDE VIEW

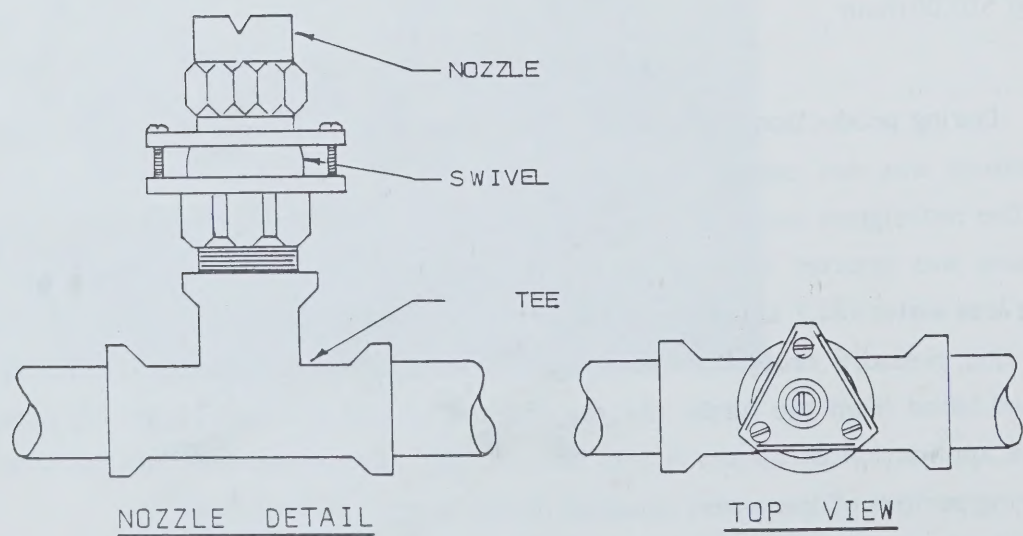


FIGURE 22

MODIFIED WHOLE BIRD WASHER

combination reduces the possible application of small orifice spray nozzles to conserve water in various areas of the plant. Booster pumps to increase water pressure in specific areas were considered, but considerable replumbing of the plant water distribution system would have been necessary. This could not have been accomplished without a plant shut-down.

The original showerheads were eventually re-installed at the whole bird washer. However, even the original bird wash system occasionally left residual feathers and blood on the birds. Therefore, a seventh shower head had to be added to increase the volume of water applied to each bird. Thus, the water use in this area actually increased from an average of 46.7 L/min to 66.4 L/min during the final monitoring period. This was equivalent to a 10 100 L/d increase in plant water consumption during production days.

Modifications to inspectors' handwashers. None of the workers' handwashers on the eviscerating line operated continuously as all had been equipped with some type of demand valve. However, at each of the four inspection stations, a gooseneck handwasher was provided. These goosenecks ran continuously to ensure a readily available supply of clean water for the inspectors.

The veterinarian-in-charge indicated that the speed required of the inspectors made a continuous flow of water preferable to any type of demand valve. Therefore, the initial modifications to the inspectors' handwashers involved the installation of flow restriction nozzles (Spraying System No. 3030 Fulljet) to the goosenecks. However, these nozzles were impractical due to the pressure variation along the eviscerating line. Excessive splashing resulted under high pressure. At low pressure, an inadequate flow was available for handwashing. Based on discussions with the inspectors and observations during visits to other poultry processing operations, Gordon-Johnson demand handwash stations were selected for evaluation. These valves, illustrated in Figure 23, are activated by the back of the hand on a lever and then run for between 10 and 30 seconds depending on adjustment and water pressure before shutting off automatically. The lever is fixed in such a position that it is washed by the fresh water flow after each usage. These demand valves were readily accepted by the inspection staff and, when a fifth inspection station was added to the evisceration line near the end of the study, a demand valve was included.

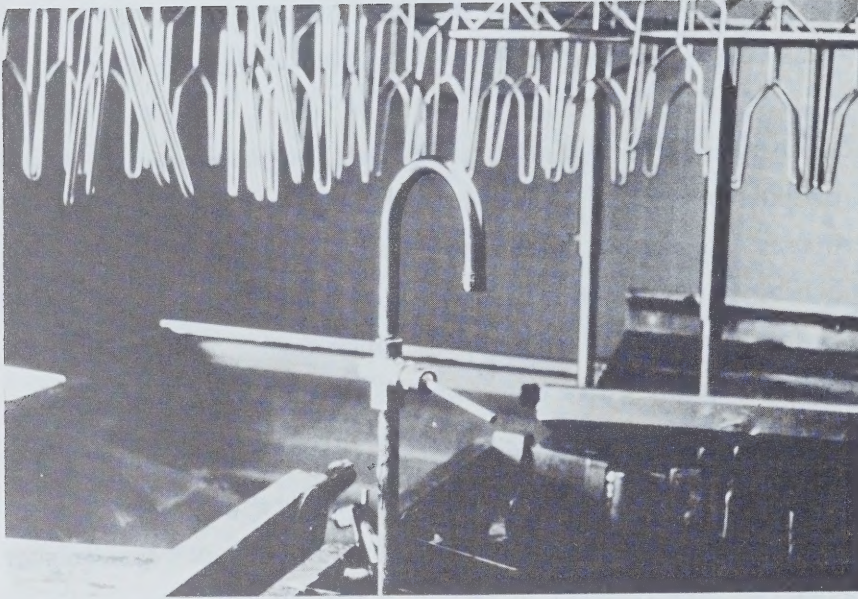


FIGURE 23 GORDON-JOHNSON DEMAND FLOW
HANDWASH STATION

This modification cost:

Materials

5 Gordon-Johnson Demand Flow Handwash Stations @ \$50.20	\$251.00
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Tax

\$ 41.74

Sub-total

\$292.74

Labour

1 hour @ \$10.00/hour

\$ 10.00

Total

\$320.74

Based on observation of the frequency of use of the handwashers, the total daily flow from the units was equivalent to approximately 820 L. This represents a reduction of more than 90 percent in the flow relative to the baseline monitoring period. The annual savings in water and sewer costs would be approximately \$366, representing a payback period of less than one year on the valves.

Despite the success of the demand valves, two problems relating to water supply were evident. At low water pressure, the valves were very slow in closing which resulted in wastage at some stations. More seriously, the internal valve mechanisms were prone to plugging with particulate iron in the water supply. Regular maintenance would be necessary to ensure proper operation if the water supply is high in iron.

Final bird washer. The original final bird washer was similar to the whole bird washer, consisting of nine low-pressure, high-volume domestic showerheads.

The final bird washer was modified in a manner similar to the whole bird washer, using the washer design of Whitehead *et al* (6). The modified final bird washer, shown in Figures 24 and 25, consisted of three parallel pipe manifolds to handle the two parallel evisceration lines. The alignment of nozzles was similar to that for the whole bird washer, spraying from the top to the bottom of the bird as it traversed the spray cabinet. A pressure regulator was included as the final bird washer was installed prior to the recognition of water pressure problems in the plant.



FIGURE 24 SPRAY NOZZLE ARRANGEMENT IN MODIFIED
FINAL BIRD WASHER

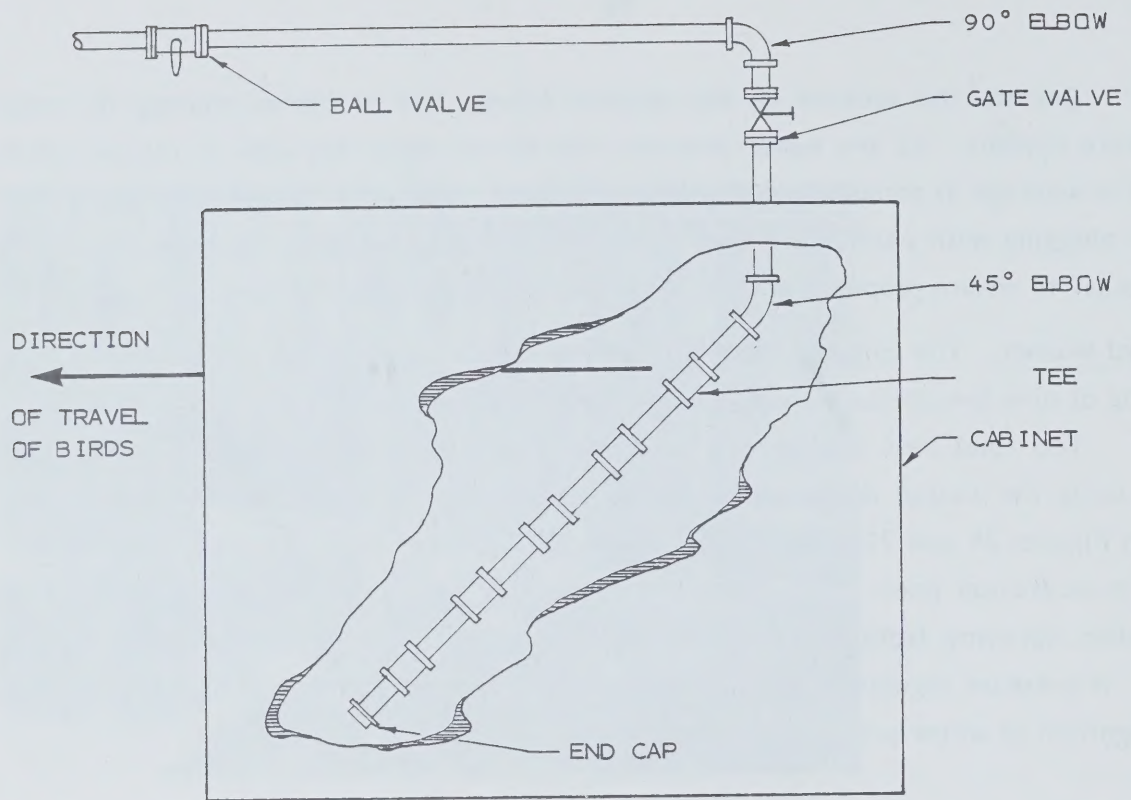
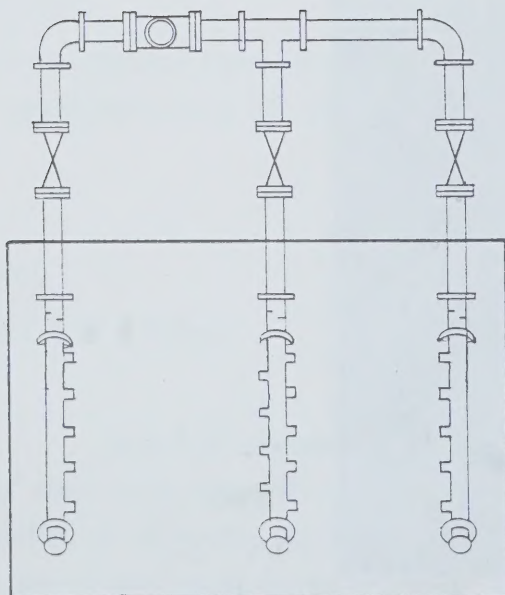
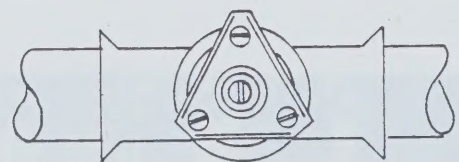
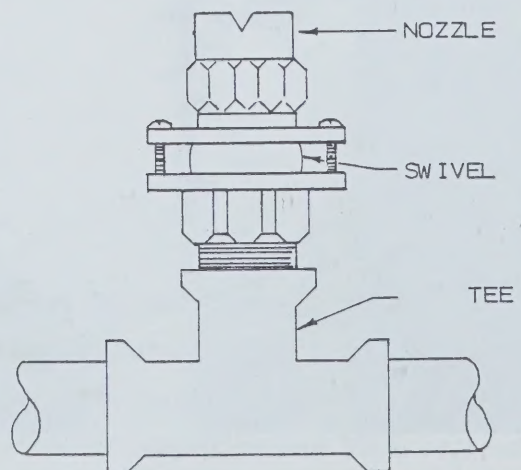
SIDE VIEWEND VIEWTOP VIEWNOZZLE DETAIL

FIGURE 25

SCHEMATIC OF FINAL BIRD WASHER

The spray manifolds held a total of 20 spray nozzles. As with the whole bird washer, some experimentation was done with spray nozzles and a combination of the same Veejet and Flatjet nozzles was selected.

The cost of modification was:

Materials

12 Flatjet Nozzles @ \$5.42	\$ 65.04
14 Veejet Nozzles @ \$1.21	\$ 16.94
14 Adjustable Joints @ \$4.13	\$ 57.82
Pressure Regulator	\$ 35.96
Miscellaneous Plumbing Supplies	<u>\$ 63.81</u>
Sub-total	\$239.57
<u>Tax</u>	<u>\$ 39.84</u>
Sub-total	\$279.41

Labour

25 hours @ \$10.00/hour	<u>\$250.00</u>
Total	\$529.41

The problems with low water pressure encountered at the whole bird washer were not as severe at the final bird washer because it is closer to the incoming town water line. However, the normal operating pressure was only 175 to 200 kPa and the pressure regulator was unnecessary. When the water pressure dropped below this level, the spray nozzles were ineffective and the original showerheads had to be used to remove residual feathers and blood.

Considerable time was spent 'fine-tuning' the spray wash system. These hours are included in the total cost of this modification. The existing spray cabinet was very narrow and considerable effort was required to realign the manifolds to provide an adequate distance between the spray nozzles and the birds. Nozzles were carefully aligned to provide adequate coverage of the birds without spraying outside the shower cabinet.

The efficiency of the modified shower system was closely examined by plant inspection staff. It was generally acknowledged that the spray nozzles were as effective as the original showerheads when adequate water pressure was available. However, when water pressure was low, the spray nozzles were not as effective, particularly for removal

of residual feathers. Therefore, during much of the final monitoring period, the spray system was used in conjunction with two of the existing showerheads to ensure adequate feather removal.

Another problem related to bird washing became evident during the evaluation of the spray system. Whenever an accumulation of birds occurred at the rehang station because of slowdowns or shutdowns of the evisceration line, the birds became more difficult to clean adequately due to the presence of dried blood. Neither wash system was completely effective in removing this blood from the birds.

Overall, the average reduction in water consumption at the final bird wash was only approximately 20 percent, or 3800 L/d. This represents a reduction of only about \$200 in annual water and sewer costs and does not justify the time and expense involved in construction and fine-tuning of the system. However, given adequate water pressure, the payback period on the system would approach one year, and the spray system would be at least as efficient as the domestic showerheads.

Chiller and prechiller modifications. The average combined makeup rate to the chiller and prechiller was approximately 2.82 L/bird, near the quantitative requirement of 1.9 L/bird specified by the USDA. Therefore, it was considered that the makeup rates, on the average, were not excessive. However, the flow rate was set arbitrarily by opening the valve on the 2.5-cm makeup line at the start of the kill shift. The setting was adjusted frequently during the kill shift according to the condition of the chiller contents. Thus, as noted in Section 4.2.2, the instantaneous makeup rate varied considerably.

It was initially proposed to recycle chiller overflow to the prechiller, thus reducing the required prechiller makeup rate. However, considerable concern was expressed by plant management and the veterinarian-in-charge regarding the effect on moisture pickup during immersion. Some makeup water or increased ice usage would also be necessary in the prechiller to maintain the desired temperature. The chiller and prechiller were arranged in such a way that pumping would be necessary to transport the overflow water. The water would also require screening to remove grease. Preliminary estimates to provide the necessary stainless steel pump and piping, along with the increased labour involved in cleaning the equipment indicated that costs approaching \$3 000 would be incurred. The minimum payback period on the cost of the modification would be approximately two years if all fresh water makeup to the prechiller was eliminated. In addition, the cost of the modification approached the budgetary limit on the project.

As an alternative, flow control valves that could be preset to the desired flow rate were installed on the makeup lines. These valves, it was hoped, would reduce the variation of the chiller makeup rates considerably.

The cost was:

Materials

2 Dresser Hancock Flow Control Valves @ \$138.00	\$276.00
Miscellaneous Plumbing Supplies	<u>\$ 8.64</u>
Sub-total	\$284.64
<u>Tax</u>	<u>\$ 47.34</u>
Sub-total	\$331.98

Labour

2 hours @ \$10.00/hour	<u>\$ 20.00</u>
Total	\$351.98

Although the variation of water use in the prechiller and chiller was reduced slightly, the average usage was not affected significantly. The flow control valves could not be preset in such a way that they could not be adjusted because some operator control of the makeup rate was necessary to compensate for variation in processing rates and quality of birds. The operators also tended to open the 5-cm main water line to the chiller and prechiller if higher flow rates were desired and could not be obtained through the flow control valves. This negated any advantage that might have been obtained from the installation of the valves.

Agriculture Canada may allow reuse of chiller water in the prechiller as this procedure is equivalent to the use of a single chiller. The problems associated with moisture pickup can be solved by controlling agitation, temperature and retention in the chiller. However, where pumping is necessary and water and sewer costs are low, the installation and maintenance of such a system in an existing plant is probably not justified by reductions in water consumption.

Modifications to grease trap. Flow from the chiller, prechiller, giblet chillers and floor drains is pretreated in a simple grease trap prior to discharge to the biological treatment plant. One of the influent pipes discharged from a point approximately 0.75 m above the surface of the trap, causing considerable turbulence and reducing the efficiency of the grease recovery system.

A simple extension and 90-inch elbow were placed on the pipe to discharge approximately 5 cm above the grease trap. Scrap materials were used and the labour involved only minutes, so no significant costs were associated with this modification.

The quantitative impact of this change is difficult to estimate. The worker in charge of manually removing the grease from the trap reported easier grease removal but could not verify any increase in the quantity of grease recovered. As discussed in more detail in Section 4.2.7, process effluent sampling indicated an overall reduction of 20 kg/d of oil and grease to the biological treatment plant. These data are inconclusive and any reduction cannot be traced directly to this modification, but it is indicative of the type of changes that could have an impact on waste loadings in some plants at no cost to the plant.

Fine tuning of process equipment. In many unit operations, water usage associated with a process is set arbitrarily by plant personnel by opening a valve without regard for how much water is actually needed to adequately maintain cleanliness or process efficiency. Examples include sprays on the rehang conveyor and evisceration equipment, giblet flume water, gizzard processing water, packing machine cooling water and giblet chiller water.

No actual modifications were made to these unit processes; however, during the final monitoring period attempts were made to manually reduce these flows.

Overall, an average reduction of approximately 7000 L/d was accomplished. Although the annual savings are relatively small, they were accomplished with no capital expenditure. However, it is necessary that plant personnel be continuously aware that maximum water flow is not necessary at all times in these areas. Such water reductions are difficult to maintain for a long period of time due to the increased operator attention required. It is not feasible to mechanically limit the flow in these areas as varying amounts of water may be required depending on conditions in the plant.

Gizzard processing represents almost 20 percent of the total population-related consumption of water at the Checkerboard plant. The high water consumption is inherent to the design of the equipment and necessary to ensure sanitary conditions. Some fine-tuning can be accomplished but the savings are minimal. Major redesign of the equipment would be necessary to accomplish any significant savings.

General plant maintenance. The plant equipment was well maintained from a processing standpoint. However, during the baseline monitoring period, leaks in piping valves were identified as a problem area which could be readily solved. For example, eleven of the valves on the 14 wash hoses on the evisceration line leaked continuously. Several valves in other areas of the plant could not be turned off completely.

To eliminate some of the undefined background usage, a concerted effort was made by plant maintenance and study personnel to repair leaks in piping systems and valves. As a part of this program, two unused goosenecks on the eviscerating line were also eliminated. The cost of the increased maintenance was negligible.

A considerable reduction in the undetermined plant water usage was noted after the leaks were eliminated. Weekend water use also decreased considerably. Although the reductions may not have been the direct result of the increased maintenance, it is felt that a continuous usage of approximately 22.7 L/min was eliminated.

The time that plant personnel are able to commit to this type of maintenance depends on the condition of the plant processing equipment. Obviously, the processing equipment requires the highest priority. However, a regular program to repair leaks in piping networks should be scheduled as frequently as possible.

Plant cleanup. Except in the receiving area, minimal dry cleanup was practised. Solids were flushed to the floor drains or evisceration trough by open-ended hoses running continuously. The high-pressure sanitizing system did minimize water usage during the cleanup shift.

Although an attempt was made to persuade cleanup staff to practise more dry removal of solids, this was generally unsuccessful. Expansion in plant capacity and, in particular, the installation of automatic equipment has resulted in a compact plant with little open floor area. Thus, dry cleanup around equipment is very time-consuming. As labour costs are considerably higher than water and sewer costs, extensive dry cleanup was not felt to be economic at this plant. Rather, Strahman M-70 Water Saver nozzles were installed on the major cleanup hoses to replace the existing 1.25 cm x 0.6 cm reducers. These automatic shut-off valves ensured that the hoses would not be left running unnecessarily and improved the flow distribution. Several of the nozzles were fitted with swivels to facilitate movement about the plant by the operators.

The cost of modifications was:

Materials

6 Strahman M-70 3/4-inch Water Saver Nozzles @ \$67.20	\$403.20
4 3/4-inch Swivels @ \$17.60	<u>\$ 70.40</u>
Sub-total	\$473.60
<u>Tax</u>	<u>\$ 78.76</u>
Sub-total	\$552.36

Labour

1.5 hours @ \$10.00/hour

\$ 15.00

Total

\$567.36

The precise impact of the water saving nozzles on the plant water usage was difficult to quantify. The overall water usage associated with the cleanup shift was reduced by approximately 13 percent to an average of 126 500 L/d. This was attributed to a combination of better operator attention to water usage and the modified nozzles. The undetermined usage, which includes the usage associated with cleanup during breaks, was also reduced.

4.2.6 Effect of Modifications on Water Use. The period from March 23 to May 4 was selected to represent the post-modification conditions at the plant. Most of the in-plant modifications had been completed and plant personnel had been informed of the goals of the study and their cooperation requested by plant management. This period represents a comparable production schedule to that utilized to define the baseline water use. The two periods are compared in Table 25. Although there is a slight difference in the number of birds processed per day (approximately two percent less during the final monitoring period), these data are considered sufficiently comparable to allow comparison of the baseline and post-modification water and waste loadings at the plant.

The post-modification water use, $473.5 \text{ m}^3/\text{d}$, represents an annual water use of $172\,828 \text{ m}^3$. The baseline water use was $197\,100 \text{ m}^3$ annually. The modifications resulted in an annual reduction of approximately $24\,272 \text{ m}^3$ in water consumption at the Checkerboard plant, or 12.3 percent compared to the baseline figure.

Based on the meter readings taken during post-modification monitoring, the average water use on a production day at the Checkerboard plant was 699.4 m^3 . On a production basis, water usage was equivalent to 23.58 L/bird. The production-day water use for the two periods of intensive monitoring can be summarized as:

Period	Daily Consumption (m^3)	Consumption per bird (L/bird)
Baseline	763.1	25.19
Post-modification	699.4	23.58

TABLE 25 COMPARISON OF BASELINE AND POST-MODIFICATION WATER USE AND PRODUCTION DATA, CHECKERBOARD FOODS LTD.

	Baseline Period (Dec. 5, 1978 - Feb. 3, 1979)	Post-Modification Period (March 23, 1979 - May 4, 1979)
Total Number of Days	60	42
Number of Production Days (P)	41	28
Number of Non-Production Days (N)	19	14
Ratio P/N	2.16	2.00
Production:		
Total Birds Processed	1 241 798	830 529
Birds per Processing Day	30 288	29 661
Water Consumption:		
Total Water Consumption (m ³)	32 396	19 887
Average Daily Consumption (m ³)	539.9	473.5
Average Consumption Per Bird (L/bird)	26.11	23.95

A post-modification production day water balance is given in Table 26. These data are compared with similar baseline data in Table 27.

Overall, the in-plant modifications resulted in a reduction of approximately 8.3 percent in the production-day water usage. The unit processes where water use was most significantly reduced were the coop wash (49 percent reduction), the inspectors' handwashers (93 percent reduction) and the final bird washer (16 percent reduction). The final post-modification study period water consumption data includes an increase in water use of 10 100 L/d in the whole bird washer. This increase was a result of problems encountered in consistently attaining adequate washing of the birds after defeathering and was not experienced during the baseline monitoring period. If the baseline water use for this unit operation is used in place of the higher post-modification water use, the daily consumption during processing days is reduced to 689.3 m³, a reduction of approximately 10 percent relative to the baseline condition.

A large fraction of the 63.7 m³ of water saved on production days was associated with the cleanup shift (19.0 m³/d) and the undetermined usages such as cleanup during breaks and piping leaks (13.3 m³/d).

TABLE 26 PRODUCTION-DAY POST-MODIFICATION WATER USAGE,
CHECKERBOARD FOODS LTD.

Unit Process	Flowrate (L/min)	Daily Consumption (litres)
Production Processes		
Coop Wash	32.5	16 600
Stunner	11.3	5 750
Automatic Killer	11.3	5 750
Scalder	56.7	45 000*
Pickers 1)	24.7	12 600
2)	23.3	11 900
Whole Bird Washer	66.4	33 900
Hock Cutter	2.5	1 275
Rehang Conveyor	17.3	8 823
Automatic Evisceration Equipment	29.5	15 050
Side Pan Wash	45.0	25 000
Inspectors' Handwashers	1.6	820
Workers' Handwashers	-	10 000
Giblet Pumps & Flumes	15.0	7 650
Gizzard Processing	-	80 900
Final Bird Washer	39.6	20 200
Prechiller	-	62 500*
Chiller	-	58 000*
Giblet Chillers	16.3	8 300
Packing Machines	2.9	1 460
Thawing Frozen Products	-	4 500
(Sub-total)		435 978
Ancillary Uses		
Ice Making	-	30 000
Vacuum Seal Water	-	49 000
Heating	-	8 800
Freezer Floor Defrost	7.1	3 600
Sanitary	-	18 500
(Sub-total)		109 900
Cleanup		
Trucks and Receiving Area	-	4 200
Cleanup Shift	-	122 300
(Sub-total)		126 500
Undefined Uses		
(e.g., miscellaneous leaks cleanup during kill shift)	-	27 009
PRODUCTION-DAY TOTAL	-	699 387

* Daily consumption includes initial filling of tank.

TABLE 27 COMPARISON OF BASELINE AND POST-MODIFICATION DAILY WATER USE DATA, CHECKERBOARD FOODS LTD.

Unit Process	Daily Consumption (litres)	
	Baseline Period	Post-Modification Period
Production Processes		
Coop Wash	32 600	16 600
Stunner	5 750	5 750
Automatic Killer	5 750	5 750
Scalder	45 000*	45 000*
Pickers 1)	11 800	12 600
2)	13 300	11 900
Whole Bird Washer	23 800	33 900
Hock Cutter	1 275	1 275
Rehang Conveyor	9 300	8 823
Automatic Evisceration Equipment	17 860	15 050
Side Pan Wash	25 000	25 000
Inspectors' Handwashers	11 100	820
Workers' Handwashers	10 000	10 000
Giblet Pumps & Flumes	7 650	7 650
Gizzard Processing	84 400	80 900
Final Bird Washer	24 000	20 200
Prechiller	65 700*	62 500*
Chiller	58 000*	58 000*
Giblet Chillers	8 900	8 300
Packing Machines	1 770	1 460
Thawing Frozen Products	4 500	4 500
(Sub-total)	467 455	435 978
Ancillary Uses		
Ice Making	30 000	30 000
Vacuum Seal Water	49 000	49 000
Heating	8 800	8 800
Freezer Floor Defrost	3 600	3 600
Sanitary	18 500	18 500
(Sub-total)	109 900	109 900
Cleanup		
Trucks and Receiving Area	4 200	4 200
Cleanup Shift	141 275	122 300
(Sub-total)	145 475	126 500
Undefined Uses		
(e.g., miscellaneous leaks cleanup during kill shift)	40 260	27 009
PRODUCTION-DAY TOTAL	763 090	699 387

* Daily consumption includes initial filling of tank.

The effect of the increased maintenance to eliminate leaks in the piping systems is most evident from the post-modification water consumption on weekends or non-production days. After the modifications, the daily consumption was 21.7 m^3 , or approximately 15.1 L/min . Comparable data during the baseline period were $58.4 \text{ m}^3/\text{d}$ and 40.6 L/min . This is consistent with the estimated reduction of about 22.7 L/min accomplished by simply repairing leaking valves and pipes.

Based on the post-modification monitoring period at the Checkerboard Foods Ltd. poultry processing plant, the following comparison summarizes the impact of the in-plant water and waste management program on plant water consumption:

	Baseline Period	Post-Modification Period
<u>Water Use:</u>		
Average Production Day (m^3)	763.1	699.4
Average Non-Production Day (m^3)	58.4	21.7
Equivalent Annual Usage (m^3)	197 100	172 830
<u>Production-Based Use:</u>		
Total (L/bird)	26.11	23.95
Production Day (L/bird)	25.19	23.58

4.2.7 Effect of Modifications on Waste Loads. The results of composite sampling of the effluents from the kill shift and cleanup/maintenance shifts during the post-modification monitoring period are given in Tables 28 and 29, respectively. The total effluent loadings, based on these samplings and the post-modification flow data are summarized in Table 30.

Comparison with the baseline process effluent loading data indicates that, with the exception of oil and grease, the total process effluent loading actually increased subsequent to the in-plant modifications. The pre- and post-modification conditions are compared in Table 31. There was no significant difference between the BOD_5 , suspended solids and total Kjeldahl nitrogen loadings during the production shift before and after the changes. However, the loadings from the cleanup shift increased in terms of all four parameters.

The reasons for the increased loadings during the cleanup shift could not be determined. It is possible that, because of the warmer weather during the post-modification period, the cleanup was more intensive even though less water was used. It

TABLE 28 POST-MODIFICATION PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, CHECKERBOARD FOODS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
April 23/79	809	412	196	73.2
April 24/79	867	510	108	165
April 25/79	910	540	80.6	168
April 26/79	1 020	524	91.8	99.2
April 30/79	1 440	838	134	527
May 1/79	1 150	420	78.4	378
Average	1 030	541	115	235

TABLE 29 POST-MODIFICATION NON-PRODUCTION SHIFT* PROCESS EFFLUENT CHARACTERISTICS, CHECKERBOARD FOODS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
April 23/79	415	178	187	169
April 24/79	800	422	111	129
April 25/79	713	228	57.1	91.2
April 26/79	980	388	94.1	154
April 30/79	1 150	728	21.3	313
May 1/79	1 120	1 070	155	348
Average	863	502	104	201

* The non-production shift represents the combined cleanup and maintenance shifts.

is also possible that the characteristics of the live birds changed between the two sampling periods, although the plant processed broilers of similar weight during each period.

The difference between the daily waste loads were not statistically significant. Therefore, despite modifications to the blood tunnel and grease trap, no reduction in process effluent waste load could be documented based on these samplings.

The performance of the biological treatment system was observed to be considerably better during the post-modification period than during the baseline monitoring period, although occasional high concentrations of suspended solids were noted in the

TABLE 30 POST-MODIFICATION PROCESS EFFLUENT WASTE LOAD, CHECKERBOARD FOODS LTD.

	Parameter			
	BOD ₅	Suspended Solids	Total Kjeldahl Nitrogen	Oil and Grease
<u>Production Shift:</u>				
Average Concentration (mg/L)	1 030	541	115	235
Loading (kg)	464	243	152	106
<u>Non-Production Shift:</u>				
Average Concentration (mg/L)	863	502	104	201
Loading (kg)	215	125	26	50
<u>Total Production Day:</u>				
Concentration (mg/L)*	970	526	114	217
Daily Loading (kg/day)	680	368	78	156
Production-Based Loading (kg/1000 birds)	22.9	12.4	2.6	5.1
(kg/1000 kg LWK)	13.1	7.1	1.5	2.9

* The average effluent concentration for a production day was calculated from the total daily waste loading and the average production day water use (699.4 m³/d).

TABLE 31 COMPARISON OF BASELINE AND POST-MODIFICATION TOTAL PROCESS EFFLUENT WASTE LOADS

	Baseline Period	Post-Modification Period
Total Production-Day Load (kg)		
BOD ₅	626	680
Suspended Solids	343	368
Total Kjeldahl Nitrogen	63	78
Oil and Grease	176	156
Production-Based Loading (kg/1000 birds)		
BOD ₅	20.7	22.9
Suspended Solids	11.3	12.4
Total Kjeldahl Nitrogen	2.1	2.6
Oil and Grease	5.8	5.1

effluent due to poorly settled biological floc. Based on limited treated effluent sampling, the average quality of the discharge to the municipal sewer system was:

Total BOD ₅	=	44 mg/L
Suspended Solids	=	15 mg/L

The vast improvement in the plant performance cannot be related directly to the in-plant modifications. Flow reductions were not sufficiently great to improve plant performance to this degree and no significant reduction in organic loading was found.

During part of the period prior to post-modification monitoring (February 3 to March 23, 1979), the poultry plant operated at a relatively low production rate. On several occasions, only 15 000 birds were processed during the day. The reduced production, in combination with warmer weather and increased oxygen transfer from the aerators, was probably the principle reason for improved treatment plant performance. Towards the end of the final monitoring period, treatment performance again began to deteriorate due to a proliferation of filamentous microorganisms in the biological treatment plant.

4.2.8 Economic Implications. The basic premise behind water and waste conservation programs is that the cost of any minor in-plant modifications can be rapidly recovered by reductions in water and sewer costs. The Checkerboard plant is charged, based on consumption, for water supplied by the Town of Aurora. An additional charge is levied for sewer services as the plant discharges to the municipal sewer system. The fee schedule for 1979 is given in Table 32. Sewer charges decrease slightly as monthly consumption increases. As the water saved would have been billed at the lowest rate (\$0.106/m³/month), the total cost of water and sewer services applied to the reduction in water usage was \$0.146/m³ (\$0.66/1000 lgal).

TABLE 32 TOWN OF AURORA WATER AND SEWER RATES

	\$/m ³ /month	\$/1000 lgal/month
Water:	0.106	0.48
Sewer:		
up to 227 m ³ /month (50 000 lgal)	0.055	0.25
227 to 1 137 m ³ /month (50 000 to 250 000 lgal)	0.044	0.20
1 137 m ³ /month (250 000 lgal)	0.040	0.18

Total cost of all modifications at the plant, including unsuccessful modifications such as the whole bird washer and the nozzles installed in the defeathering machines, was:

Materials	\$2 124.04
Tax	\$ 350.78
Labour	<u>\$ 785.16</u>
Total	\$3 259.98

This total does not include the cost of purchasing and installing flow metering equipment which was approximately \$1575. In addition, the time invested by the consultants in flow measurement, sampling, equipment selection and in-plant observation is not included in this total cost figure.

The reduction in annual water consumption, 24 272 m³, is equivalent to a total savings of \$3528.50 annually in water and sewer costs at the 1979 rate of

\$0.146/m³/month (\$0.66/1000 lgal/month). The total direct cost of the modifications would be paid back in approximately one year. The total direct cost of the successful modifications which actually effected these savings was about \$2000. Thus, these modifications resulted in a payback period of less than one year.

No decrease in contaminant loading could be determined as a result of the study. However, as the plant operates its own pretreatment facility and the Town of Aurora does not levy a surcharge on high-strength wastes, a small reduction in waste loading would have little impact on the plant operating costs.

4.2.9 Summary of the Water and Waste Conservation Program at Checkerboard Foods Ltd. The modifications to the Checkerboard Foods Ltd. poultry processing plant resulted in an overall reduction of approximately 12.3 percent in the annual plant water consumption. There was no significant effect on the plant waste loading.

The actual monetary saving resulting from the modifications was approximately \$3500, adequate to pay for the materials and labour associated with the changes in about one year. However, the savings may not justify the time involved in implementing and maintaining an intensive water management program at this plant. Water and sewer costs are low compared to those levied elsewhere (see Appendix C). In addition, the Checkerboard plant has already succeeded in reducing its water usage to a relatively low level without specifically emphasizing water and waste management.

The major problem encountered in attempting to implement various modifications in the plant was low water pressure. Although this reduced the degree of success during the demonstration study, it appears to be an important factor contributing to the generally low water use in the plant under normal conditions.

The veterinarian-in-charge at the Checkerboard Foods plant was accurate in stating that a reduction in water use below about 23 L/bird would be difficult to attain without major modifications. The usage actually attained as a result of the study was 23.58 L/bird.

4.3 Prime Packers Ltd.

4.3.1 Plant Description. Prime Packers Ltd. operates a slaughterhouse in Toronto, Ontario. The plant is located in a highly urbanized area and is about 20 years old. It has been gradually expanded from a small family operation to a large slaughterhouse capable of producing in the range of 10 to 15 million kilograms dressed weight annually.

Prime Packers slaughters beef, sows, calf and lamb. The 1978 kill was 38 965 beef (11.16 million kilograms dressed weight) and 322 calves and lambs (17 259 kg dressed weight). The daily kill varies depending on the availability of livestock, making it very difficult to select a 'typical' period of operation at the plant. Normally, the sow kill occurs early in the morning. The beef kill commences at the end of the sow kill and continues into the afternoon depending on the number of animals in the stables. During most of the winter 1978/79, there was a shortage of beef and prices were inflated. Therefore, the plant slaughtered more sows than normal. The plant was shut down for a number of days during February and March, 1979, due to the high price of livestock. During the spring of 1979, beef became more readily available and contributed a greater fraction of the daily kill.

Calf and lamb slaughtering occurs relatively infrequently and, as was evident from the 1978 production data, does not make a major contribution to the total plant output. During the baseline monitoring period, no calves or lambs were slaughtered at the plant. During the post-modification monitoring period, a total of 77 calves were killed on five separate days. No lambs were killed. Because of the relatively small contribution of calf and lamb slaughter to the total plant production, no attempt was made to separately determine the water use and waste loadings associated with these phases of the operation and no modifications specific to the calf and lamb slaughter were made.

The slaughter of beef and sows occurs on the same kill floor; however, the unit operations associated with each are slightly different.

Beef cattle, normally purchased from the Ontario Stock Yards, are held in an enclosed stable for varying lengths of time prior to being shunted into the stun chute. The animals are stunned by a conventional handheld stunner and hoisted onto the kill rail. The immobilized animals are stuck on the kill platform and the operator collects approximately 25 L of whole blood in a pail from each animal. The whole blood is centrifuged and edible plasma collected. The residual red blood cells are discharged to the sewer along with the remaining blood not collected from the animal.

After the cattle have been bled, they are transferred to the dress rail. The hide is removed from the head and rear hooves. The head and hooves are then removed. The head is transferred to the head dressing area where it is washed and trimmed. The carcass is split up the belly and the hide removed by a combination of manual trimming and, finally, mechanical hide pulling. The hides are dropped automatically to the basement where they are trimmed and sold green to a tannery.

Viscera are removed from the carcass, inspected and edible organs separated. All inedible viscera, including the intact paunch, is dropped to the basement through chutes on the kill floor. The carcass is split, kidneys removed, the carcass trimmed and weighed, washed and shrouded, and placed in the freezers.

Most of the beef is wholesaled as halves or quarters; however, there is also a boneless beef operation in the plant. Trimmings from the deboning operation and from the kill floor are collected in drums and dumped into a steam-heated batch cooker. The cooker is normally run once a day to produce edible tallow. The dry proteinaceous materials from the cooker are removed manually and placed in the basement level viscera auger to be transferred to an outside container which is picked up daily by an independent renderer.

Sows are normally slaughtered the same day that they are purchased and are rarely stabled. They are unloaded directly from trucks to runways leading to the kill floor. The sows are stunned electrically and hoisted to the bleed area, where they are stuck. All sow blood is discharged to the sewer system.

After bleedout, the sows are scalded by immersion in a steam-heated scald tank and mechanically dehaired. The carcass is then hung from the dress rail and a series of polishing steps performed to remove residual hair and bristles. The carcass is rinsed, singed, showered and manually shaved. From this point, the sow and beef operations are very similar and the same basic equipment is used. The carcass is opened, viscera removed and inspected. The carcass is split, trimmed and finally washed before entering the freezers. Sow are not shrouded.

The kill area at Prime Packers is compact. A plant layout is shown in Figure 26.

4.3.2 Baseline Water Use. Prime Packers Ltd. purchases water from the City of Toronto. Consumption is monitored by a Rockwell water meter. Potable water is used throughout the plant for processing and cleaning.

The baseline data collection phase of the program covered two months from December 5, 1978 to February 9, 1979. Most of the water use data collected, with the exception of total plant consumption, were based on instantaneous measurements. Because of the inaccessibility and complexity of the water supply system, there were few areas where water meters could be readily installed and monitored.

Water consumption during sow and beef kills were similar, although the consumption was related to different operations in the plant. The production-based water

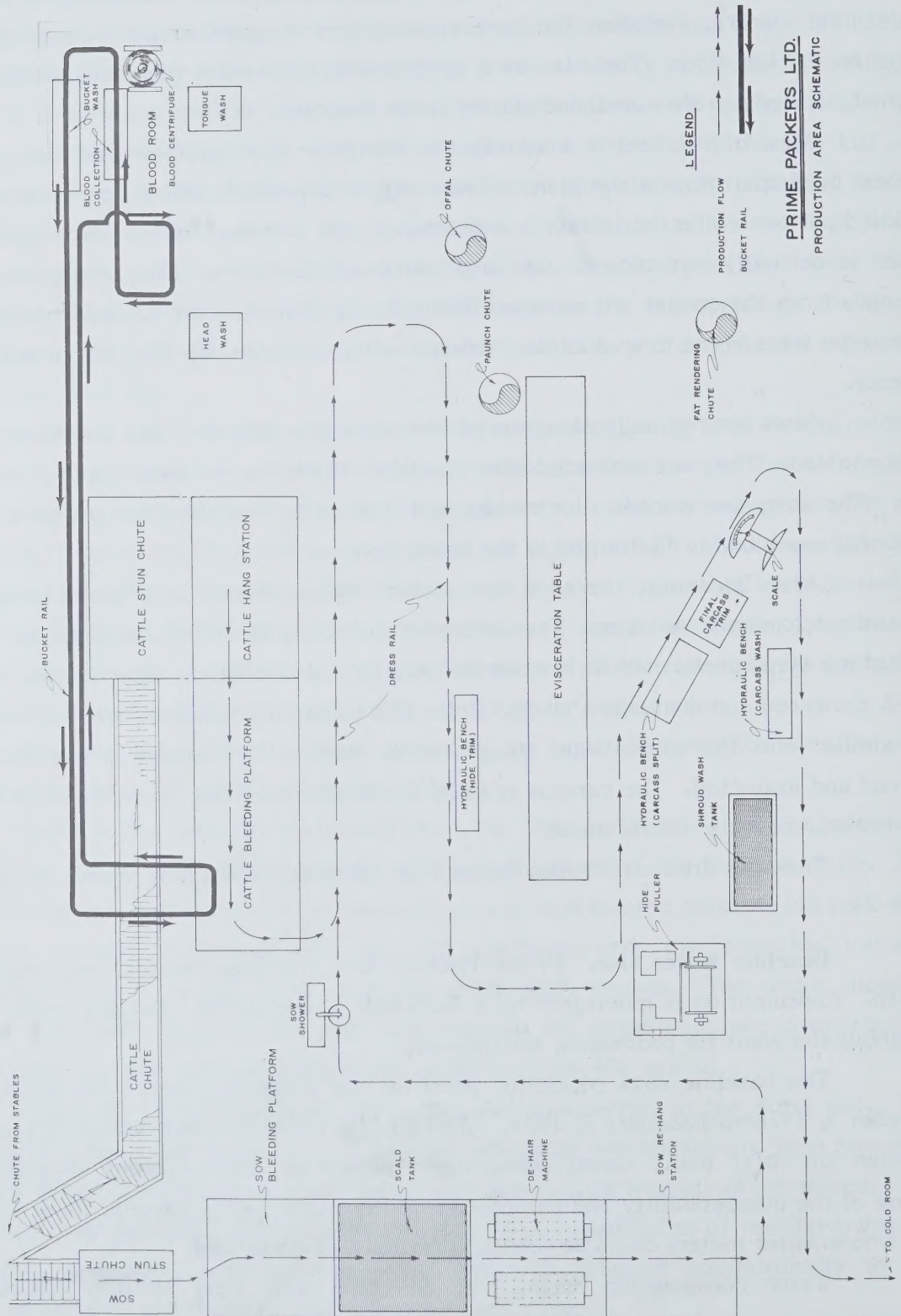


FIGURE 26 PRIME PACKERS LTD. PRODUCTION AREA SCHEMATIC

uses (litres per kilogram dressed weight) were also similar during sow kills and beef kills. Although the average dressed weight of beef carcasses (286 kg) is considerably higher than that of sow carcasses (156 kg), sows are processed more rapidly than beef resulting in similar water consumption on a weight basis. During the baseline monitoring period, the comparative average weight-based water consumptions were 6.0 L/kg dressed weight for sows and 6.5 L/kg dressed weight for beef.

In the following discussion, the water consumption related to the various unit processes involved in sow and beef slaughtering are discussed separately. However, daily and annual water quantities relating to sow and beef kills are discussed together.

Based on the measured water consumption during the baseline monitoring period, the annual water consumption was extrapolated for a theoretical year consisting of 245 production days and 120 non-production days. The data used for this extrapolation are summarized in Table 33. Annual water consumption at Prime Packers Ltd. prior to the in-plant modifications was determined as 98 329 m³. This is equivalent to an average daily use, including production and non-production days, of 269.4 m³.

Based on daily water meter readings taken during the baseline monitoring period, the average water use on production days was 353.0 m³/d. On a dressed weight basis, this was equivalent to 6.29 L/kg. The plant does not record the live weight of animals prior to slaughter. The water consumption on production days represented about 75 percent of the annual water use.

On a production day, the kill shift normally commences at 0700 hours and is completed by around 1500 hours. However, the duration of the kill depends on the availability of livestock. The kill floor is normally washed down at lunch break but the major cleanup occurs between the completion of the kill shift and approximately 2100 hours. From the completion of the cleanup shift to the commencement of the next kill shift, there is very little activity in the plant.

The water use associated with each unit process during a production day is discussed in subsequent subsections. A production-day water balance for the baseline monitoring period is given in Figure 27. These data are presented on an hourly basis as the length of time that each unit process operates depends on the relative numbers of sow and beef available at the plant. Therefore, it is difficult to calculate the average daily water use associated with each unit process.

Stables. Typically, cattle are bought and slaughtered the same day, eliminating the need to feed and water them for very long. When cattle are kept in the stables overnight or

TABLE 33 BASELINE WATER USE, PRIME PACKERS LTD.

Total Water Used During Baseline Period	15 116 m ³
Daily Water Use	
Production Day	353.0 m ³ /d
Non-Production Day	98.7 m ³ /d
Daily Production	
Beef	
Number of Animals	131
Dressed Weight	37 300 kg
Sows	
Number of Animals	124
Dressed Weight	19 500 kg
Production Based Water Use (L/kg Dressed Weight)	
Beef	6.47 L/kg
Sows	5.96 L/kg
Overall	6.29 L/kg
Equivalent Annual Water Consumption	98 329 m ³

over a weekend, the water use varies with the number of animals and the temperature. In general, drinking water is provided on an 'as needed' basis. Watering troughs are filled manually as they become empty. At no time during the demonstration study were open valves or overflowing troughs observed. Due to the high variability and relatively insignificant quantity of water involved, no precise measurements were made in this area.

Kill stations - sows and beef. The major water use associated with the sow and beef kill stations is a shower provided for the sticker so that he can wash his hands and arms after each animal. These showers ran continuously during kills at an average rate of approximately 1400 L/h for the beef kill and 700 L/h for the sow kill.

Blood handling system - beef. After each beef is stuck approximately 25 L of whole blood is collected. This blood is tagged so that it can be identified with a particular animal and

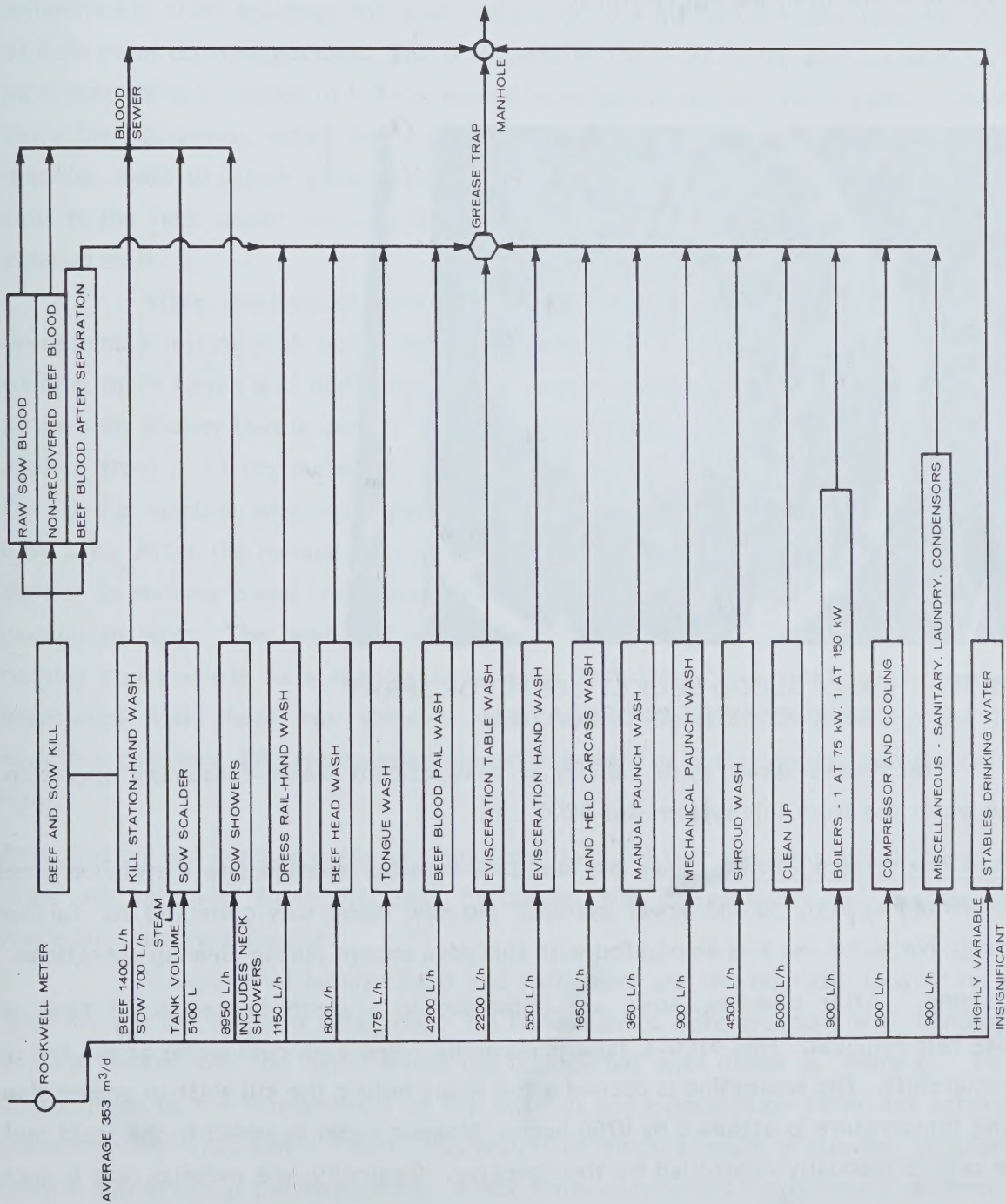


FIGURE 27 PRIME PACKERS LTD.: BASELINE WATER BALANCE

placed on a conveyor which moves at the same rate as the carcass line. The blood, if acceptable for edible products, is centrifuged and the plasma collected for marketing. The residual red cells are discharged to the sewer. After emptying, the buckets are conveyed through a spray shower before being returned to the kill station to be refilled. The spray cabinet is shown in Figure 28. All beef blood not recovered for separation is discharged to sewer from the kill platform.

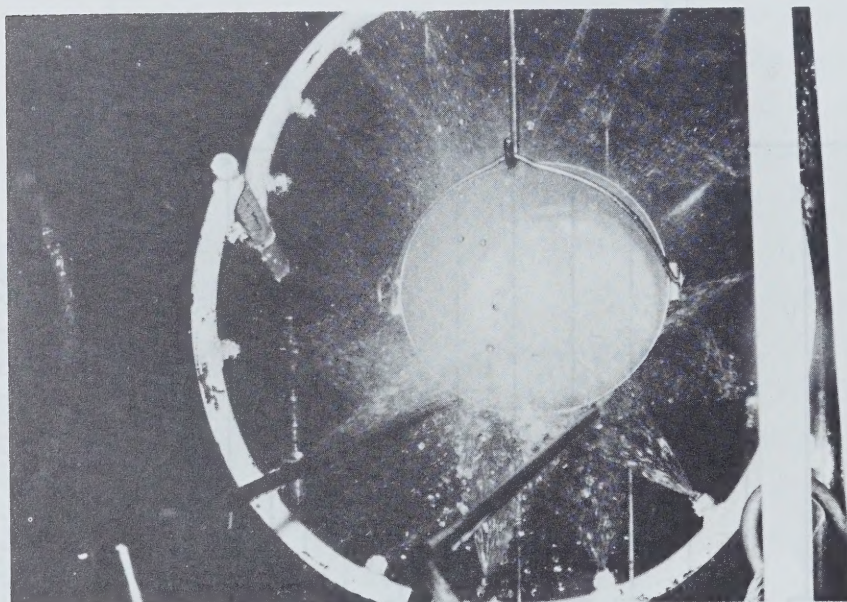


FIGURE 28 BEEF BLOOD BUCKET CONVEYOR SPRAY WASH CABINET IN OPERATION

The bucket spray wash cabinet is a significant water-consuming operation. Average water use from this system was 4200 L/h.

Blood handling system - sows. Sows are bled in a vertical position into a stainless steel tank connected directly to the sewer system. No sow blood was collected for further processing. No water use was associated with this area except during cleanup operations.

Sow scalding. After bleeding, sows are immersed in a steam-heated scald tank to facilitate hair removal. This 5100-L tank is normally filled with cold water at the end of the cleanup shift. The steam line is opened a few hours before the kill shift to ensure that operating temperature is attained by 0700 hours. Makeup water is added to the scald tank and the rate is manually controlled by the operator. Typically, the makeup rate is such

that minimal overflow occurs and the water just compensates for the amount carried out of the scalding by the sows. This makeup rate is highly variable and insignificant relative to the total volume of the scald tank.

Sow dehairing. Water applied to facilitate mechanical and manual removal of hair from the sow carcasses represents a large fraction of the total water usage during the sow kill. Immediately after scalding, the sows are placed in a mechanical dehairing unit consisting of a series of rotating paddles. This unit removes the most of the carcass hair. A 1.3-cm pipe containing a number of 0.3-cm drilled holes sprays the carcass to remove some of the loose hair; however, water use is minimal because the rotating action of the dehairing machine tends to splash water onto the operators. Hair removed in the dehairing machine falls to the floor under the machine and is removed dry in drums for disposal during the cleanup shift.

After mechanical dehairing, the carcass is polished in a number of manual operations involving high water use. The carcass is washed down manually with a hose running at 36 L/min and then singed. The largest consumption of water, however, occurs in the body shower that is used to lubricate the carcass prior to manual shaving. Water is applied from a 15-cm domestic showerhead above the carcass, as shown in Figure 29. During the baseline monitoring period, this shower ran continuously at a rate averaging 6500 L/h. After the manual shaving of the carcass, it was passed through a head and neck shower to remove blood from the stick wound and moisten the head and shoulders for manual shaving. The head and neck shower was a single 2.5-cm domestic showerhead running continuously at a rate equivalent to 2450 L/h. The total hourly water usage associated with these two showers was approximately 9000 L during the baseline monitoring period. This represented almost one-third of total consumption during the sow kill.

Evisceration and carcass dressing - sows and beef. After the sows are dehaired and the hides are removed from the beef carcasses, the evisceration and carcass dressing procedures are very similar.

A number of handwashers and sterilizers are strategically located on the kill floor for the use of plant personnel. All handwashers were equipped with hand-operated demand valves and the total water use associated with these is minimal. The total consumption of the handwashers on the kill rail and evisceration table was estimated at approximately 1700 L/h. Plant personnel had already made a number of changes to control water use in the sterilizers. These units overflowed continuously, as required by

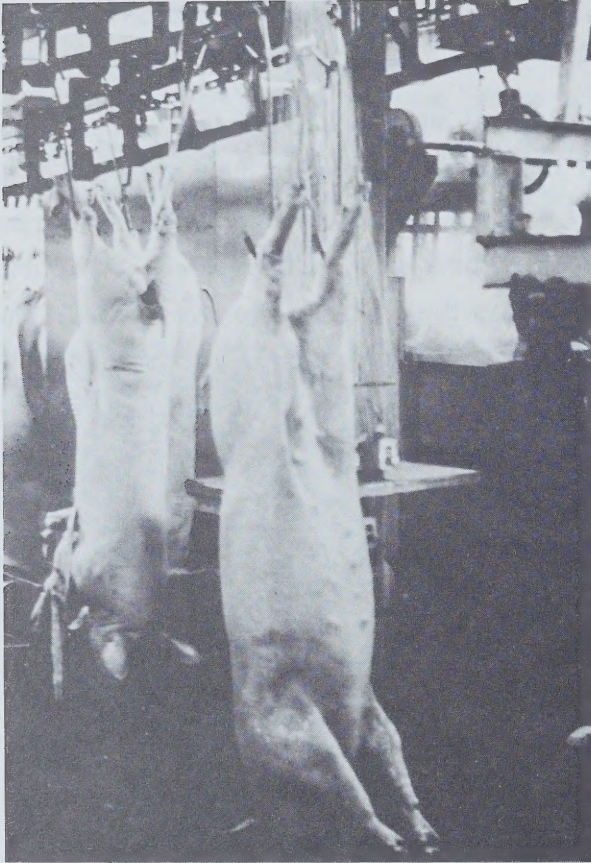


FIGURE 29 ORIGINAL SOW SHOWER SYSTEM

the Department of Agriculture. However, inlet pipes to the sterilizers had been reduced in size to about 0.3 cm to control the overflow rate. In addition, a timer-solenoid valve system had been installed to turn off the sterilizers automatically at the end of the kill shift. Each individual sterilizer used approximately 50 L/h.

The major water usage was associated with cleaning and sterilizing the moving evisceration table. The table is equipped with three 2-cm lines feeding hot water, warm water and cold water through spray nozzles. During the kill shift, only the warm and cold water lines are used resulting in a water usage of 2200 L/h. During cleanup, all three lines are opened fully. Water consumption during this period was included in the cleanup total.

Final carcass wash - sows and beef. Final carcass washing for both sows and beef is done manually at Prime Packers rather than in a spray wash cabinet. A hand-operated spray

nozzle is used. This practice, it is felt, reduces indiscriminate water use and improves cleanliness as the operator can apply water directly to areas which visibly appear to need further washing. The rate of water usage at the carcass wash station was approximately 1650 L/h.

Shrouding - beef. Sows are not shrouded prior to refrigeration. However, beef are covered with a white cloth to reduce water loss and protect the meat. Shrouds are kept in a 3600 L tank. During the baseline period, a continuous cold makeup water flow was maintained to this tank at a rate of 4500 L/h. This flow was intended to keep the water clear and cold and prevent the buildup of slimes on the shrouds. The number of hours per day that the shroud wash water ran varied considerably. On some occasions it ran continuously 24 hours per day; on other occasions, the makeup line was shut off during the cleanup shift and re-opened in the morning. It was occasionally left running over weekends, contributing to high non-production day usages.

Head trim station - beef. After the head is removed from the beef carcass, it is transferred to the head dress station. It is placed on a rack and washed with hand-held hoses equipped with water saver valves. The meat is trimmed off and the tongues removed. The tongue is placed in a wash tank which is continuously overflowing and mixed with air. Total water use associated with the head dressing is approximately 975 L/h, of which 175 L/h is used in tongue washing. During the sow kill, tongues are removed and placed in the same wash tank. The remainder of the head is disposed of with viscera and bones.

Viscera handling - beef. After inspection, edible organs are removed, washed and placed on a rack to be taken to the freezers. Inedible organs, with the exception of the paunch, are dumped through a chute directly into an auger in the basement which transfers this material into an outside container. The container is picked up regularly by an independent renderer.

The intact paunch is dumped down a separate chute to the basement paunch handling station. The paunch is opened and the contents dry-dumped to a holding tank. The tripe is then washed on an umbrella or in a mechanical tripe washer depending on the demands of the various purchasers. The units use 360 L/h and 900 L/h, respectively.

The paunch manure is transferred by compressed air from the holding tank to an outside container for ultimate disposal.

Viscera handling - sows. All inedible sow viscera are dumped directly from the kill floor to the auger for disposal to the renderer.

Ancillary usage. Water associated with such processes as compressor cooling, refrigeration, boiler blowdown and sanitary uses was estimated based on water meter readings taken after the completion of the cleanup shift or, where possible, by instantaneous measurements. Estimates of these flows are included in Figure 27.

Cleanup. The major cleanup operation at the plant commenced at the completion of the kill shift. Total water usage was monitored from the main water meter and corrected for known background uses. The water usage averaged about 5000 L/h during the six to seven hours of cleanup, resulting in a total cleanup water use of about 35 000 L/d. The cleanup usage represents about 10 percent of the production day usage.

At the start of the cleanup shift, most of the gross solids are swept to the viscera chutes and into the basement auger. Strategically-located drums on the kill floor are used to reduce the quantity of gross solids which accumulate on the floor during the kill shift. Sow hair is removed dry to an outside container. After most of the large solids are removed, the floors are washed using high-pressure hot (80°C) water. During the first hour of cleanup, six hoses are used; one in the stable-runway area, one in the coolers, one in the basement, two on the kill floor, and one in the beef blood separation room. These hoses discharge at a rate of 82 to 91 L/min. Most of the plant has been cleaned thoroughly after about one hour. However, cleanup on the kill floor continues for an additional two hours. Finally, all equipment on the kill floor is scrubbed manually and rinsed to complete the cleanup.

The plant has a portable high-pressure cleanup system; however, this equipment is used only during shutdowns to sanitize walls, floors and equipment. It was found that the use of this equipment for general cleanup significantly increased the time and labour required to complete the plant cleanup.

Based on meter readings taken at the beginning and end of shifts during production days at the plant, the following shift breakdown of average water use was determined for the baseline monitoring period:

<u>Shift</u>	<u>Water Use (m³)</u>
Production (Kill) Shift	211.8
Cleanup (Evening) Shift	88.5
'Background' (Night) Shift	<u>52.7</u>
Production Day Total	353.0

The 'background' shift is the period between the completion of the clean-up shift and the beginning of the next kill shift. There is generally very little activity at the plant during this period. Of the water used during the 'background' shift shroud washing contributed almost 70 percent.

Non-production day water usage during the baseline study period averaged 98.7 m^3 . This varied depending on whether the non-production day was during a weekend or a shutdown due to lack of livestock. The critical factor in determining non-production day usage was the shroud washer. If this was left operating continuously, non-production day usage approached $150 \text{ m}^3/\text{d}$.

4.3.3 Baseline Waste Loads. Process effluents from Prime Packers are discharged to the municipal sewer system. Two grease traps are the only pretreatment provided. Tripe wash water is discharged through a small trap to collect residual manure and grease. Bone dust and grease from the latter stages of the evisceration process are collected in a second grease trap. Blood sewers serving the early stages of the killing operation go directly to the municipal sewer, bypassing the traps. The grease traps are cleaned manually.

All process effluents discharge through a manhole to the city sewers. Composite samples were taken during the kill, cleanup and background shifts to define the process effluent loading during the baseline monitoring period. There was no means to measure process effluent flow. Estimates of the per-shift water consumption were used to calculate effluent loadings. The production shift and non-production shift sampling results are summarized in Tables 34 and 35. The total process effluent loadings are tabulated in Table 36. The minimal cleanup conducted between sow and beef kills made it extremely difficult to accurately segregate the waste loadings associated with each killing operation. Therefore, these data are presented without reference to the actual type of kill in progress. Production-based waste loads were calculated on the basis of the total dressed weight of carcasses.

The production-based process effluent BOD_5 loading, $12.4 \text{ kg}/1000 \text{ kg}$ dressed weight, is relatively high. This is principally a result of the large quantities of blood discharged to the sewer system. The calculated average production-day concentration is well in excess of the Metro Toronto discharge bylaws, as indicated by the comparison in Table 37. The municipality has an overstrength surcharge system which contributes to the high sewer and water charges levied against Prime Packers. More details regarding the effect of the surcharge on plant operating costs is provided in subsequent discussions of the economic impact of the in-plant water and waste management program.

TABLE 34 BASELINE PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, PRIME PACKERS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
Jan. 11/79	1 123	400	-	-
Jan. 12/79	3 250	710	-	-
Jan. 16/79	800	191	116	93
Jan. 17/79	4 650	460	634	298
Jan. 23/79	2 800	330	445	117
Jan. 24/79	1 800	630	239	219
Feb. 1/79	1 430	190	156	61
Feb. 2/79	7 690	560	535	91
Average	2 940	434	354	146

TABLE 35 BASELINE CLEANUP AND BACKGROUND* SHIFT PROCESS EFFLUENT CHARACTERISTICS, PRIME PACKERS LTD.

Shift	Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil & Grease (mg/L)
Cleanup	Jan. 15/79	200	54	7.3	630
Cleanup	Jan. 19/79	1 125	3 800	231	648
Cleanup	Feb. 1/79	890	200	80	111
Cleanup	Feb. 2/79	923	280	130	68
Cleanup Average		785	1 083	112	364
Background	Jan. 22/79	140	192	-	-
Background	Jan. 30/79	260	1 720	-	-
Background	Feb. 1/79	435	150	2.5	226
Background	Feb. 2/79	204	80	18.2	23
Background Average		260	535	10.4	124

* The "background" shift represents the period between the completion of the cleanup shift and the start of the next kill shift.

TABLE 36 BASELINE PROCESS EFFLUENT WASTE LOAD, PRIME PACKERS LTD.

	BOD ₅	Suspended Solids	Total Kjeldahl Nitrogen	Oil & Grease
<u>Production Shift:</u>				
Average Concentration (mg/L)	2 940	434	353	146
Loading (kg)	623	92	75	31
<u>Non-Production Shift:</u>				
Average Concentration (mg/L)	785	1 083	112	364
Loading (kg)	69	96	10	33
<u>Background Shift:</u>				
Average Concentration (mg/L)	260	535	10.4	124
Loading (kg)	14	28	0.6	7
<u>Total Production Day:</u>				
Concentration (mg/L)*	2 000	611	240	200
Loading (kg)	706	216	85	71
Production-Based Loading (kg/1000 kg)**	12.4	3.8	1.5	1.3

* The average effluent concentration for a production day was calculated from the total daily waste loading and the average production day water use (353.0 m³).

** Production-based loading is calculated on the basis of total dressed weight of carcasses.

TABLE 37 COMPARISON OF PROCESS EFFLUENT QUALITY AND
METROPOLITAN TORONTO BYLAW LIMITS

Parameter	Average Concentration (mg/L)	Metro Toronto Bylaw Limits (mg/L)
BOD ₅	2 000	500
Suspended Solids	611	600
Total Kjeldahl Nitrogen	240	-
Oil and Grease	200	150

Because of the complexity of the sewer system and space constraints on the kill floor, no sampling of individual waste streams was conducted at the Prime Packers plant.

4.3.4 Plant Attitudes. Plant management at Prime Packers were very concerned about the rapidly rising costs of water and sewer services. The implementation of an overstrength surcharge had particularly affected the operation. Based on the schedule outlined in Table 38 and the estimated strength of the plant process effluent, the total cost to the plant was approximately \$0.35/m³ (\$1.60/1000 lgal). The cost per kilogram of BOD₅ in excess of the bylaw limit had increased by almost 50 percent between 1978 and 1979. From early discussions with plant management, it was evident that there was a lack of understanding of the surcharge levy. They felt that they were being charged a minimum amount and that reducing the waste load would not affect the surcharge. However, after the method of calculating the sewer surcharge was understood, plant management became very receptive to the goals of the proposed program and were willing to provide complete cooperation.

Some in-plant modifications had already been made to control water usage, such as the installation of flow restrictors and timer-solenoids on the sterilizers. In addition, work had commenced on an air-cooled heat exchanger to replace the water-cooled unit which had been used for the refrigeration system. The average baseline water use, 6.29 L/kg dressed weight, is relatively low for the industry (see Appendix B). Thus, considerable control of excessive water use was evident in the plant although no formal conservation program had been in effect.

TABLE 38 MUNICIPALITY OF METROPOLITAN TORONTO WATER AND SEWER CHARGES AND INDUSTRIAL WASTE SURCHARGE CALCULATION

Basic Water and Sewer Charge	21.2¢ per m ³ (96.6¢ per 1000 lgal)
Sewer Service Charge (13% of Basic Charge)	2.8¢ per m ³ (12.6¢ per 1000 lgal)
Surcharge Formula (Annual Cost, \$)	$\$ = V \times F \times G \times C$ $V = \text{volume of annual discharge in Imperial gallons}$ $F = 10^{-5}$ $G = \text{excessive concentrations of SS, grease or BOD}_5 \text{ in mg/L, whichever is greatest in excess of the bylaw limits}$ $C = \text{Cost Factor} = \$0.077/\text{kg} \text{ } (\$0.035/\text{lb})$

Plant employees were primarily European butchers who were very conscientious about minimizing water use and controlling the amount of solid waste thrown on the floor. The viscera chutes to the basement level auger were very useful in this regard. The only major problem was communication, as many of the employees spoke little English. It was difficult to ensure that the purpose of a particular modification or the desired operating procedure was completely understood.

As at the other plants involved in the demonstration studies, Health of Animals inspection staff, and particularly the veterinarian-in-charge, were receptive to the goals of the program and extremely cooperative throughout the in-plant study period.

4.3.5 Modifications. Excessive process effluent waste load, due to the discharge of large quantities of blood, was identified during the baseline monitoring period as one of the major areas where improvements could be made at the plant. Although water usage was not excessive, several areas of possible improvement were also identified. The individual modifications made in the plant are discussed in detail below. In the case of modifications affecting in-plant water usage, it was difficult to estimate the actual daily reduction in usage because of the variation between processes that are operated on any particular day. Reductions in water consumption and the economic impact of the modifications are discussed in more detail in Sections 4.3.6 and 4.3.7.

Blood collection system. All blood, with the exception of the plasma separated from about 25 L of whole blood collected from each beef carcass, was discharged to the sewer system. This contributed a major fraction of the effluent BOD₅ load during both the kill shift and cleanup shift. A considerable quantity of this blood was considered recoverable. As approximately one-third of the total plant water and sewer bill was related to the excess BOD₅ load, considerable savings could be realized through in-plant collection of blood.

Two 2270-L rectangular polyethylene tanks on stainless steel support stands were installed in the basement to collect blood from the kill floor. These tanks were interconnected so that they filled simultaneously. An air-operated diaphragm pump was installed to transfer the blood through a flexible rubber pipe to an outside holding tank. This tank was provided at no charge by the company that purchased the blood and was emptied daily.

Blood originates from three major sources on the kill floor: the sow bleed-out area, the beef kill platform and the whole blood centrifuge in the blood separation room. Because of the number of drains involved, the distance between the drains, the complexity of the existing sewer system and the cost of major modifications to the kill floor, it was not considered feasible to install a completely separate drainage sewer to divert only blood to the holding tanks. Therefore, the existing sewer lines were interconnected in the basement and diverted to the blood tanks. As the same drains would be used for cleanup of the kill floor, a system of 10-cm butterfly valves was installed to divert cleanup water away from the blood tanks and into the main plant sewer. The blood collection system is shown in Figure 30.

A schedule of operation was developed by the plant personnel for the blood collection system. At the commencement of the kill shift, the valve to the main sewer was closed and the valve to the collection tanks was opened. At the end of the kill, residual blood was swept down the sewer to the tank. Prior to washdown of the kill floor, the valve to the collection tanks was closed and the cleanup water was sewerred. At the same time, the blood collected during the kill was pumped to the outside holding tank. The tanks were then washed and the wash water pumped to the main sewer.

The cost of this modification was:

Materials

Two 2 270-L polyethylene tanks with covers and fittings	\$1 413.04
PVC Pipe and Fittings	443.37

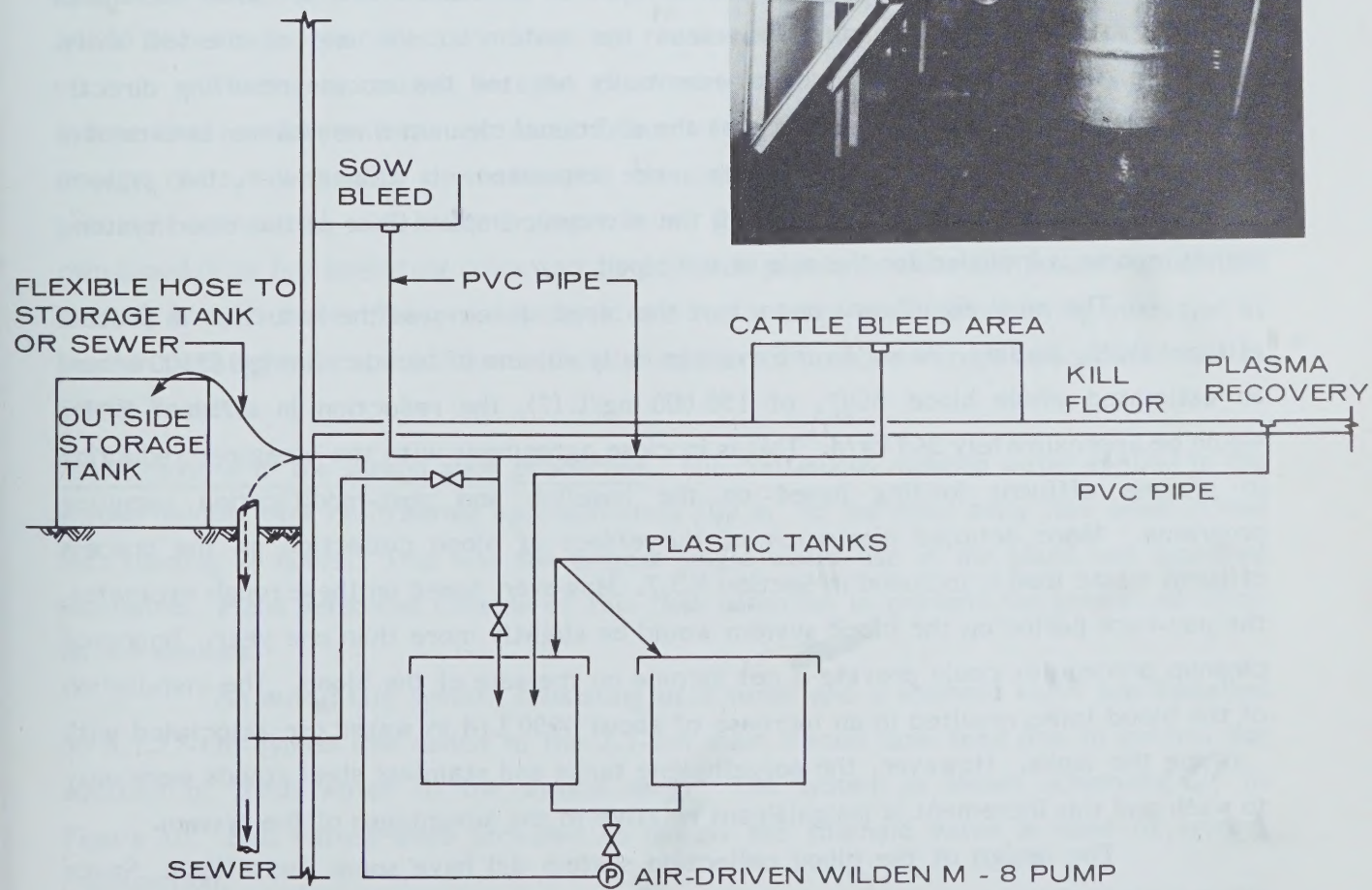
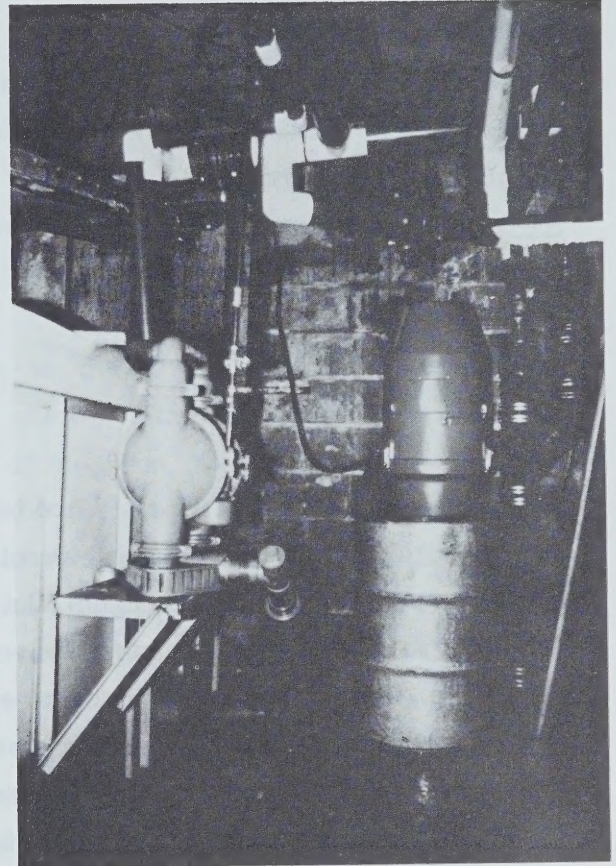


FIGURE 30

BLOOD COLLECTION SYSTEM AT PRIME PACKERS LTD.

Stainless Steel (304) Angle Iron	1 557.35
Wilden M-8 Pump	1 050.00
Two 10-cm PVC Butterfly Valves with flanges, etc.	1 050.60
	5 514.36
<u>Tax</u>	917.04
Sub-total	6 431.40
<u>Labour</u>	
130 hours @ \$10/h	1 300.00
Total	7 731.40

An average of 13 to 17 t of blood per week were collected after installation of the collection system. The blood was sold for \$18/t, resulting in a gross income of \$250 to \$300/week. The cleanup personnel claimed that an additional two to three hours was required to pump out the tank and clean the system at the end of the kill shift. Therefore, the additional labour costs essentially negated the income resulting directly from the sale of the blood. It is felt that the additional cleanup time claimed is excessive and will be reduced substantially after more experience is gained with the system. However, for the purposes of evaluating the economic implications of the blood system, no net income is included for the sale of the blood.

The most significant impact of the blood system was the reduction in process effluent BOD₅ loading. Based on the average daily volume of blood collected (2500 L) and an estimated whole blood BOD₅ of 150 000 mg/L (7), the reduction in effluent BOD₅ would be approximately 365 kg/d. This is in close agreement with the measured reduction in process effluent loading based on the baseline and post-modification sampling programs. More detailed discussion of the effect of blood collection on the process effluent waste load is included in Section 4.3.7. However, based on these rough estimates, the pay-back period on the blood system would be slightly more than one year. Improved cleanup procedures could provide a net income on the sale of the blood. The installation of the blood tanks resulted in an increase of about 5000 L/d in water use associated with washing the tanks. However, the polyethylene tanks and stainless steel stands were easy to wash and this increment is insignificant relative to the advantages of the system.

The design of the blood collection system did have some limitations. Space constraints in the basement determined the size and dimensions of the holding tanks. The two polyethylene tanks required substantial support when full and would not necessarily be

the most cost-effective alternative in another situation. Similarly, the air-operated diaphragm pump was used because it was a spare available at the plant. The 10-cm butterfly valves created a flow restriction in the sewer which could cause plugging problems although none were experienced during the study. The valving arrangement had to be checked and changed at various times during the day to ensure that water was not discharged to the blood tank. Despite these limitations, the blood system performed adequately throughout the study.

There was still excessive blood loss to the sewer during the beef kill in particular. The loss was a result of the limited space available on the kill platform for carcass bleed-out. Considerable accumulations of blood on the floor under the kill line could not be recovered in the blood system because there was insufficient space on the kill floor to install additional troughing without seriously interfering with carcass and employee movement. Considerable redesign of the kill floor and the plant sewer system would be necessary to collect the blood not recovered on the kill platform.

Finding a market for the recovered blood was also a problem. Several independent renderers were approached, but were reluctant to accept the blood. High energy costs, along with corrosion and abrasion to equipment, were cited as major problems associated with blood drying. Prime Packers had, at one time, operated their own blood drier but operating costs and air pollution problems made the process unfeasible on such a small scale. The present buyer operates a large-scale blood drying operation at its own packinghouse and purchases from a number of smaller outside operations such as Prime Packers.

Modifications to the shroud wash procedure. The continuous makeup water applied to the shroud holding tank contributed approximately 103 m^3 to the total daily flow when it was left running 24 hours. This was the largest single water use in the plant and appeared excessive. Plant personnel considered this flow essential to prevent the growth of slime on the shrouds.

An automatic system consisting of a timer and a solenoid valve was installed on a 1.25-cm bypass line added to the 2.5-cm main shroud tank feed line to control the addition of fresh water to the shroud tank. The system is shown schematically in Figure 31. Ball valves were provided to bypass the solenoid valve in case of system malfunction.

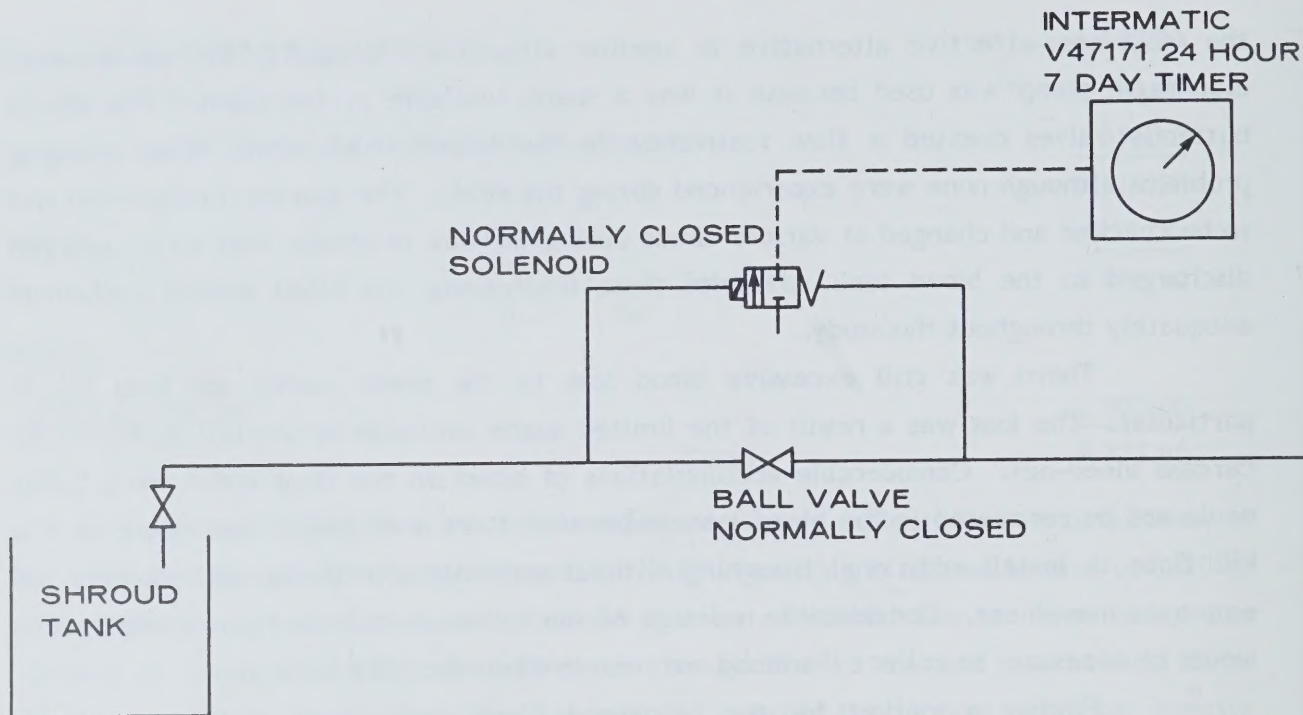


FIGURE 31 SHROUD WASH CONTROL SYSTEM

The shroud wash control system cost:

Materials

Intermatic Timer	\$124.99
Time Pins	6.00
Ball Valve	21.08
Normally Closed Solenoid Valve	62.90
Miscellaneous Copper Pipe & Fittings	5.00
	<u>\$219.97</u>

Tax

Sub-total \$256.55

Labour

6 hours @ \$10/h	60.00
Total	\$316.55

After discussions with plant personnel and inspection staff and considerable experimentation with a variety of timer settings, the system was set to open the solenoid valve for a total of 4.5 hours per day during weekdays. This included activation of the solenoid valve approximately every two hours for five minutes from 1600 hours to 0230 hours, continuous operation for two hours immediately prior to the start of the kill shift, and activation for five minutes every half-hour for the first three hours of the kill shift and every 15 minutes during the subsequent three hours of the kill shift. The timer did not activate the system on Saturdays and Sundays. The timer-solenoid valve was bypassed for approximately four hours on Monday morning for the weekly intensive washing of shrouds.

Once this schedule was implemented, there was no evidence of any deterioration in the cleanliness of the shrouds and no slime accumulation was observed. It was difficult to convince plant employees that adequate makeup water was being provided and, initially, they opened the solenoid bypass valve to provide a continuous flow to the shroud tank. However, after the system had been in operation for several weeks, it became evident that the water flow was adequate and the employees allowed the automatic system to control the rate of fresh water addition.

Modifications to the sow carcass and head showers. The sow carcass and head showers used to facilitate manual shaving of the residual hair and bristles were inefficient. These showers also ran continuously, whether or not there was a carcass in position to be washed.

A system of Fulljet spray nozzles was substituted for the domestic shower-heads to improve washing efficiency and reduce water consumption. A limit switch was mounted on the kill rail to activate a solenoid valve so that water was applied only when a carcass was in the correct position at both stations at the same time; the same limit switch-solenoid valve system was used to control both showers. The system is shown in Figure 32.

The cost of the modifications was:

Materials

Ball Valve	\$ 15.00
Normally Closed Solenoid Valve	\$ 62.90
Pressure Regulator	\$ 35.96
Limit Switch and Relay	\$114.39

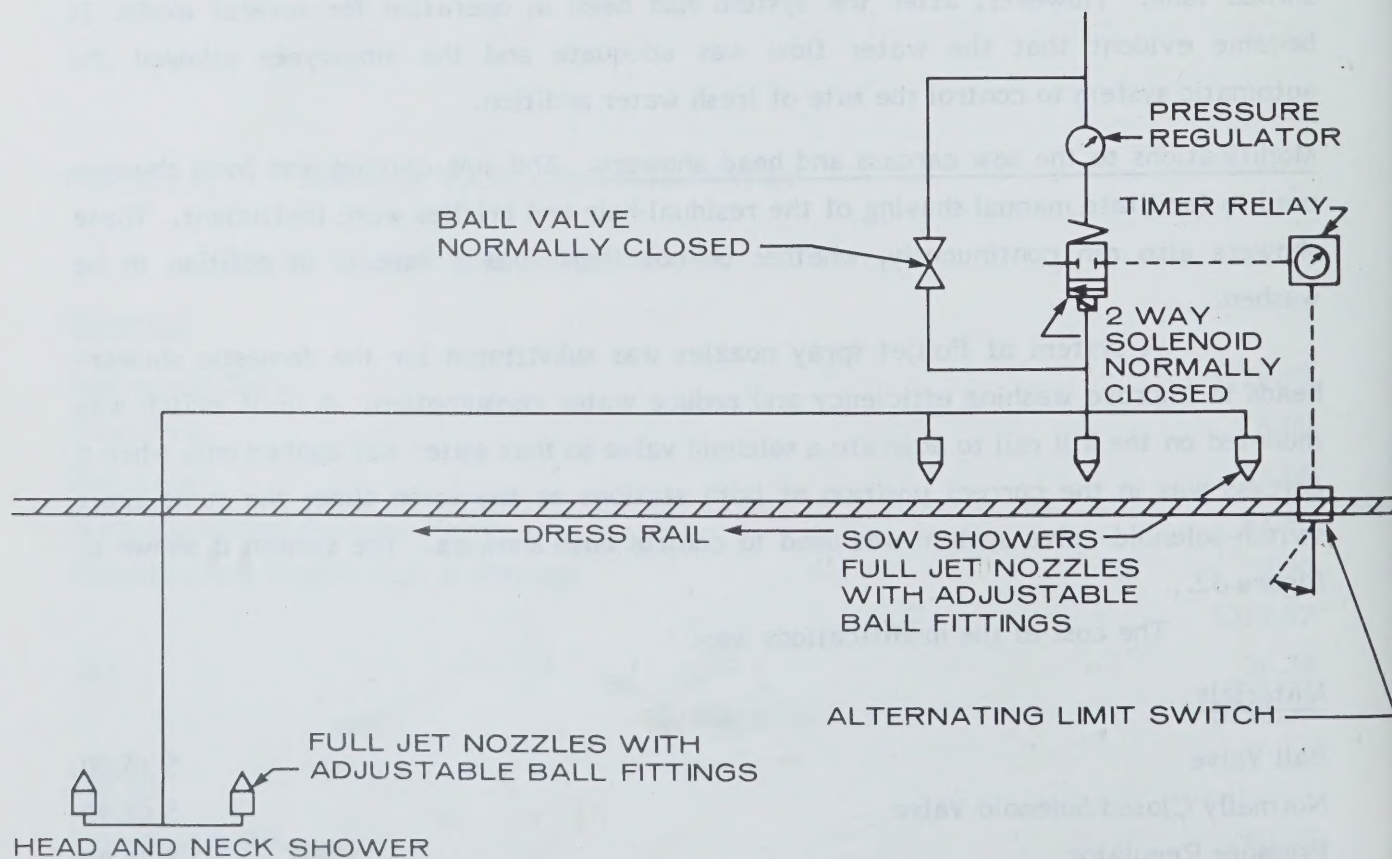
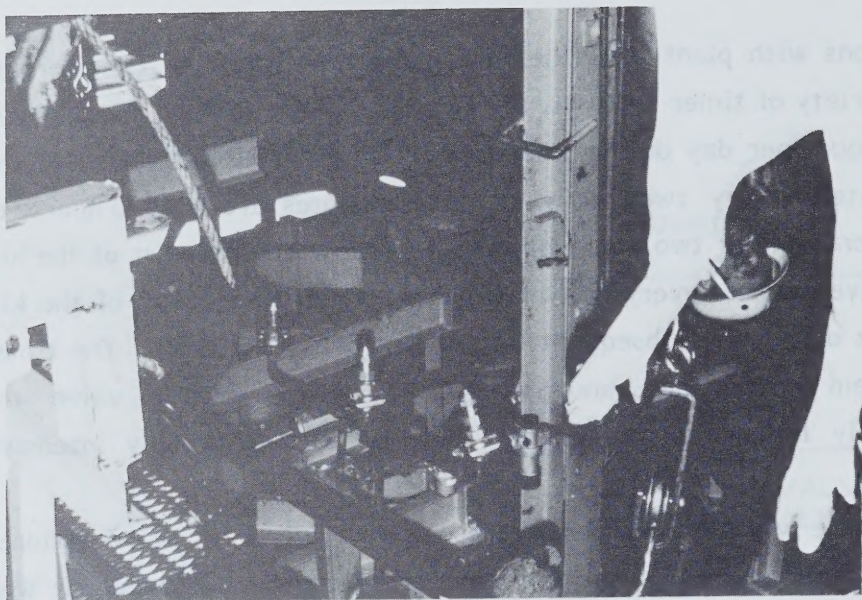


FIGURE 32 MODIFIED SOW SHOWER

3 Fulljet Nozzles	\$121.98
2 Fulljet Nozzles	\$ 26.32
3 Adjustable Joints	\$ 44.13
2 Adjustable Joints	\$ 8.26
Copper Pipe and Fittings	<u>\$ 57.86</u>
	\$486.80
<u>Tax</u>	<u>\$ 80.95</u>
Sub-total	\$567.75
<u>Labour</u>	
12 hours @ \$12/h	<u>\$120.00</u>
Total	\$687.75

The control system reduced the water usage associated with these showers by more than 90 percent. The carcass shower nozzles had a throughput of 41 L/min at the operating pressure of 375 kPa. The head shower throughput under the same conditions was approximately 12.7 L/min. At normal kill speed, the solenoid was activated for 20 seconds every 1.5 minutes during the sow kill. Thus, total hourly usage in these two showers was about 700 L, compared to 8950 L/h with the original system. The plant personnel and inspection personnel did not find any difference in the hair removal efficiency after the alterations.

The single problem with the design of the system was that, as both showers were activated by the limit switch at the carcass shower station, the head shower was not activated for the last three sows on the kill line. The heads of these three carcasses had to be washed manually with a hose.

Modifications to the beef blood bucket washer. Before the collected beef blood can be separated for edible plasma, the associated carcass must pass inspection on the kill floor. To ensure that inspection is completed before the blood is dumped to the centrifuge, the blood conveyor line is frequently stopped. However, the bucket shower cabinet continued to operate when the conveyor was stopped.

A 1.9 cm normally-closed solenoid valve was introduced on the water supply to the spray cabinet. The valve was activated by the control switch on the conveyor line, so that the water supply to the spray wash cabinet was turned off when the conveyor line was stopped. A ball valve was included in the piping system so that the solenoid valve could be stopped in case of system failure. As the spray cabinet was used occasionally for

washing specialty products such as pigs' feet, a secondary switch was installed to activate the solenoid valve when the conveyor line was not in operation.

It had been the normal procedure at the plant to start the bucket wash system at the commencement of the beef kill. However, the first bucket did not reach the spray cabinet until about 30 minutes after the start of the kill. Therefore, in addition to the mechanical modifications, the start-up time of the spray wash system was rescheduled to coincide with the first bucket entering the spray cabinet. However, the veterinarian-in-charge requested that the spray cabinet be started at the beginning of the kill shift on Monday mornings to eliminate any dust that might have accumulated in the cabinet over the weekend.

The cost of these modifications was:

Materials

Normally-Closed Solenoid Valve	\$ 69.56
Ball Valve	17.30
Copper Pipe and Fittings	<u>42.69</u>
	\$129.55

Taxes

\$ 21.54

Sub-total

\$151.09

Labour

8 hours @ \$10/hour	<u>\$ 80.00</u>
---------------------	-----------------

Total

\$231.09

The total daily savings accomplished by the modifications to the beef blood bucket spray cabinet are difficult to estimate because of the highly variable amount of use and the variation in the on-off cycles in the system. Based on observation of the system, the solenoid valve was activated for an average of about 40 minutes per hour during the beef kill. This represents a reduction of approximately one-third in the water use associated with the spray cabinet. An additional reduction of about 2000 L/d was accomplished by starting the system at the same time as the first bucket entered the spray cabinet.

Some further reduction in water use in the spray cabinet might have been accomplished by substituting lower water use nozzles for those in the system.

Kill station handwashers. Showers were provided at both the beef and sow killing stations so that the sticker could wash his hands and arms after each animal had been slaughtered. These showers ran continuously during the kill although they were actually in use for a small percentage of the time.

Plant personnel were aware of this wastage of water, particularly during the beef kill. A variety of demand valves had been tried on the beef kill platform without success. Because of the limited space on the platform, all interfered in some way with the killing operation.

A portable wash station was installed on the beef kill platform in an attempt to solve these problems. A foot-operated valve was connected to the shower head by a flexible hose and mounted on the side of the platform. The original system and the modified system are shown in Figures 33 and 34. As the sewer on the kill platform was connected directly to the blood tanks, the hand wash shower had to be mounted in such a way that water was discharged onto the kill floor and not into the kill platform blood drain.

At the sow kill station, where no space was available to mount a demand valve, the employees were instructed to control water use by reducing the valve opening to a minimum.

The cost associated with this modification was:

Materials

Foot Operated Valve	\$161.80
<u>Tax</u>	<u>26.91</u>
Sub-total	\$188.71

Labour

2 hours @ \$10/h	<u>\$ 20.00</u>
Total	\$208.71

Operator control of water use at the sow kill station was not particularly successful. Although some reduction in water use (approximately 30 percent) was accomplished, this was primarily a result of study personnel reducing the valve opening.

The modified shower on the beef kill platform reduced water use without interfering with the efficiency of the operator. The foot valve and shower could be easily moved out of the way when not required and was mounted in such a position that it was



FIGURE 33 ORIGINAL HANDWASH STATION
ON BEEF KILL PLATFORM
IN CONTINUOUS OPERATION

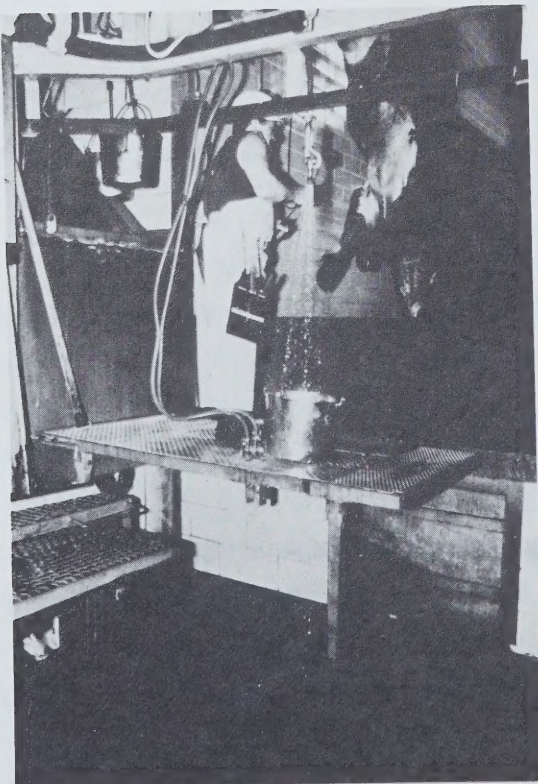


FIGURE 34 MODIFIED HANDWASH STATION
ON BEEF KILL PLATFORM
SHOWING FOOT-OPERATED
VALVE IN OPERATION

readily accessible during the beef kill. Based on the average kill rate and the approximate time required for the operator to wash his arms, hands and knife, the hourly usage was calculated to be about 75 L, compared to the original consumption of 1400 L/h.

Modifications to cleanup hoses. After removing gross solids from the floors, cleanup personnel flushed the floors with hot water from open-ended high-pressure hoses. Each hose consumed 82 to 91 L/min when in operation.

Automatic shut-off valves and nozzles on the cleanup hoses were originally proposed. However, plant personnel expressed concern about operator safety. The hoses were connected to quick-disconnect fittings so that they could be moved from room to room. It was feared that the cleanup personnel would disconnect the hose at the wall outlet without shutting off the flow. As the cleanup water temperature was about 80°C, a severe burn could result.

As an alternative, each hose was fitted with a 15-cm nipple and a stainless steel end cap. The end cap was drilled to provide a 1.0 cm orifice. This reduced the flow from each cleanup hose to the range of 55 to 65 L/min. However, cleanup staff in the stables complained that these modifications reduced the cleaning efficiency of the hoses. To improve the spray pattern from these hoses, a slit was cut across the end cap to create a wide-angle spray pattern. The resultant water use per hose in the stables was about 70 L/min.

The cost involved was:

Materials

Stainless Steel (304) End Caps	\$ 19.32
Pipe Nipples	<u>3.00</u>
	\$ 22.32
<u>Tax</u>	\$ <u>3.71</u>
Sub-total	\$ 26.03

Labour

2 hours @ \$10/h	\$ <u>20.00</u>
Total	\$ 46.03

Meter readings during the cleanup shift, corrected for the known background usages, indicated a cleanup usage of approximately 32 100 L/d compared to the baseline usage of 35 800 L/d. The water use reduction accomplished during cleanup was minimal.

However, the total post-modification usage included an additional 5000 L associated with cleanup of the blood collection system which had not been required during the baseline period. Therefore, the actual savings resulting from the modifications was approximately 8000 L/d.

Modifications to the refrigeration system. At the start of the demonstration study, Prime Packers had commenced work on a new air cooling system to replace the existing water cooled system for refrigeration. The cost of these modifications were outside the scope of the demonstration study; however, the water savings resulting from the change are included in the final water use data. Therefore, the modification and the effect on water use will be discussed briefly.

The original cooling system consisted of a recirculating cooling tower for evaporative cooling of the refrigerant. Makeup water was added on a level-controlled basis to the recirculation sump. To reduce the makeup water demand, cooling water from the plant air compressor had been recirculated to the cooling tower sump. Plant personnel estimated that, during summer months, about 2700 L/h was used. During the winter when the baseline measurements were made, the makeup rate was approximately 900 L/h. In addition to the high water usage, the cooling system was inadequate to handle the plant refrigeration load.

Plant personnel designed and installed a new air cooler for the refrigerant to eliminate the water usage associated with the original system. The new cooler was put into operation during the final monitoring period and the water usage during this period reflects the reduced usage associated with the new system. Some of the air compressor cooling water was reused in the inedible tripe holding tank.

As the original water-cooled system had to be replaced, the selection of an air-cooled system to conserve water was justified based on the reduced water and sewer costs. Capital cost of the system was estimated at approximately \$16 000. No estimate was available for the labour cost.

4.3.6 Effect of Modifications on Water Use. The period from May 9 to June 15, 1979 was selected to represent post-modification conditions at the plant. All in-plant modifications, including the air-cooled refrigerant system, had been completed and production returned to a level similar to that of the baseline period. Production data for the two periods are compared in Table 39. The number of animals killed during the two periods is comparable; however, the daily kill included more beef during the post-modification period than during the baseline period. Therefore, the average dressed

TABLE 39 COMPARISON OF BASELINE AND POST-MODIFICATION PRODUCTION DATA, PRIME PACKERS LTD.

	Baseline Period (Dec. 5, 1978 - Feb. 9, 1979)	Post-Modification Period (May 9, 1979 - June 15, 1979)
Daily Beef Production		
Number of Animals	131	182
Dressed Weight (kg)	37 300	57 720
Daily Sow Production		
Number of Animals	124	66
Dressed Weight (kg)	19 500	10 340
Total Daily Production		
Number of Animals	255	240*
Dressed Weight (kg)	56 800	68 400*

* 54 calves (dressed weight = 8 650 kg) were killed during the post-modification period.

weight per day was higher during the final monitoring period. As the daily water use is related to the dressed weight throughput of the plant, the estimates of water savings resulting from the in-plant modifications are probably conservative, particularly during the kill shifts.

The calculated water use data for the post-modification period are compared with similar data from the baseline period in Table 40.

Based on the measured consumption during the baseline period, the annual water usage was extrapolated for a hypothetical year consisting of 245 production days and 120 non-production days. The resulting figures are compared with the annual consumption during an equivalent baseline period in the following summary:

	Baseline Year	Post-Modification Year
Annual Consumption (m ³)	98 329	69 994
Equivalent Average Daily Consumption (m ³)	269.4	191.8

TABLE 40 COMPARISON OF BASELINE AND POST-MODIFICATION WATER USE, PRIME PACKERS LTD.

	Baseline Period (Dec. 5, 1978 - Feb. 9, 1979)	Post-Modification Period (May 9, 1979 - June 15, 1979)
Total Water Use (m ³)	15 116	7 128
Daily Water Use (m ³)		
Production Day	353.0	256.4
Non-Production Day	98.7	59.8
Daily Production (kg Dressed Weight)	56 800	68 400
Production-Based Usage (L/kg Dressed Weight)	6.29	3.75
Equivalent Annual Consumption (m ³)	98 329	69 994

The in-plant conservation measures resulted in an annual water saving of 28 335 m³, equivalent to 28.8 percent of the annual consumption based on the baseline monitoring data. Of this total reduction, it is estimated that approximately 7800 m³ resulted from the installation of the air-cooled heat exchanger on the refrigeration system. If this reduction is excluded, the annual water savings would be about 20 500 m³, equivalent to a 20.8 percent reduction in overall plant usage.

A post-modification production-day water balance is given in Figure 35, which can be compared to data for the baseline period in Figure 27. The in-plant modifications reduced the production-day water use to 256.4 m³ from the baseline level of 353.0 m³, a reduction of 27.4 percent. This was accomplished despite the increase in dressed weight processing through the plant.

The water usages per shift during a production day are summarized in Table 41. Modifications to the shroud washing process and the installation of the air-cooler on the refrigeration system affected the water use during all three shifts. The changes to the cleanup procedures contributed a relatively small amount to the overall reduction. The major reductions resulted during the kill shift, where the modifications to the sow showers, the kill station handwash and the beef blood bucket conveyor had a significant impact.

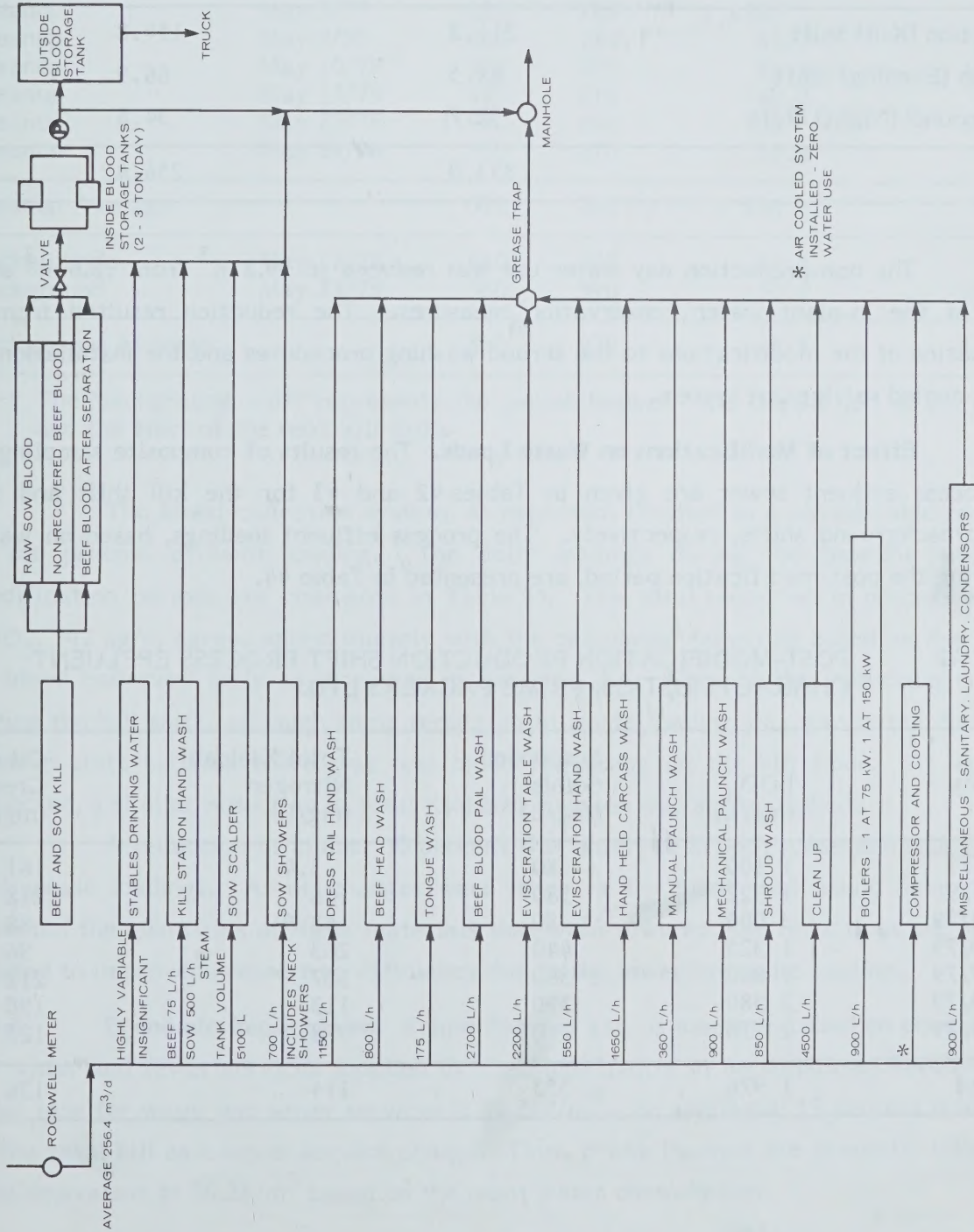


FIGURE 35 PRIME PACKERS LTD.: POST-MODIFICATION WATER BALANCE

TABLE 41 PRODUCTION DAY WATER USAGE PER SHIFT, PRIME PACKERS LTD.

	Water Use (m ³)	
	Baseline Period	Post-Modification Period
Production (Kill) Shift	211.8	154.8
Cleanup (Evening) Shift	88.5	66.9
'Background' (Night) Shift	52.7	34.8
Total	353.0	256.4

The non-production day water use was reduced to 59.8 m³ from 98.6 m³ as a result of the in-plant water conservation measures. The reduction resulted from a combination of the modifications to the shroud washing procedures and the installation of the air-cooled refrigerant system.

4.3.7 Effect of Modifications on Waste Loads. The results of composite sampling of the process effluent sewer are given in Tables 42 and 43 for the kill shift and the cleanup/background shifts, respectively. The process effluent loadings, based on water use during the post-modification period, are presented in Table 44.

TABLE 42 POST-MODIFICATION PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, PRIME PACKERS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil & Grease (mg/L)
May 8/79	1 100	80	3.4	161
May 9/79	1 322	580	106	218
May 10/79	3 000	80	48.9	88
May 15/79	1 325	440	263	96
May 17/79	1 800	1 360	187	212
May 23/79	2 580	590	113	190
May 24/79	2 710	740	78.4	125
Average	1 976	553	114	156

TABLE 43 POST-MODIFICATION CLEANUP AND BACKGROUND* SHIFT PROCESS EFFLUENT CHARACTERISTICS, PRIME PACKERS LTD.

Shift	Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil & Grease (mg/L)
Cleanup	May 8/79	225	210	381	-
Cleanup	May 9/79	220	240	49.7	67
Cleanup	May 10/79	972	270	81.8	125
Cleanup	May 15/79	425	210	40.3	73
Cleanup	May 23/79	1 380	240	108	125
Cleanup	May 24/79	330	270	35.8	80
Cleanup Average		592	240	116	94
Background	May 17/79	480	200	21.4	96
Background	May 23/79	560	340	30.2	290
Background Average		520	270	25.8	193

* The 'background' shift represents the period between the completion of the cleanup shift and the start of the next kill shift.

The blood collection system, as expected, resulted in a considerable reduction in the process effluent loading. The daily loadings during the baseline and post-modification periods are compared in Table 45. The total reduction in process effluent BOD₅, 342 kg/d, agrees approximately with the calculated reduction based on the volume of blood collected daily as discussed in Section 4.3.5. Most of this reduction occurred during the kill shift, although some reduction in waste loading was also noted during the cleanup shift because there was less blood remaining on the kill floor. As would be expected, a similar reduction in total Kjeldahl nitrogen was accomplished.

A reduction of almost 50 percent was observed in both suspended solids and oil and grease loadings. As no changes were made in the plant that would have directly affected the quantities of these materials that were sewered, the reductions are probably related to improved grease trap efficiency due to the lower hydraulic loading.

4.3.8 Economic Implications. Prime Packers Ltd. is assessed, based on consumption, for water and sewer services supplied by the Municipality of Metropolitan Toronto. The basic rate for water and sewer services is \$0.212/m³. An additional 13 percent is assessed to the total bill as a sewer service charge. Thus, Prime Packers are presently billed at a rate equivalent to \$0.24/m³ based on the plant water consumption.

TABLE 44 POST-MODIFICATION PROCESS EFFLUENT WASTE LOAD, PRIME PACKERS LTD.

	BOD ₅	Suspended Solids	Total Kjeldahl Nitrogen	Oil & Grease
<u>Production Shift:</u>				
Average Concentration (mg/L)	1 976	533	114	156
Loading (kg)	306	86	18	24
<u>Cleanup Shift:</u>				
Average Concentration (mg/L)	592	240	116	94
Loading (kg)	40	16	8	6
<u>Background Shift:</u>				
Average Concentration (mg/L)	520	270	25.8	193
Loading (kg)	18	9	0.9	7
<u>Total Production Day:</u>				
Concentration (mg/L)*	1 420	433	101	239
Loading (kg)	364	111	26	37
Production-Based Loading (kg/1000 kg)**	5.3	1.6	0.4	0.5

* The average effluent concentration for a production day was calculated from the total daily waste loading and the average production day water use (256.4 m³/d).

** Production-based loading is calculated on the basis of total dressed weight of carcasses.

TABLE 45 COMPARISON OF BASELINE AND POST-MODIFICATION PROCESS EFFLUENT WASTE LOADINGS, PRIME PACKERS LTD.

	Baseline Period	Post-Modification Period
Total Production Day Load (kg)		
BOD ₅	706	364
Suspended Solids	216	111
Total Kjeldahl Nitrogen	85	26
Oil and Grease	71	37
Production-Based Loading (kg/1000 kg)*		
BOD ₅	12.4	5.3
Suspended Solids	3.8	1.6
Total Kjeldahl Nitrogen	1.5	0.4
Oil and Grease	1.3	0.5

* Dressed weight basis.

In addition, the municipality has an industrial waste surcharge system which allows an industry to discharge over-strength wastes to the sewer if the municipality is compensated for the additional treatment costs associated with these wastes. The charge is based on the volume of waste discharged and the highest concentration excess above the bylaw limit for the four basic waste parameters, BOD₅, suspended solids, grease and phenolic compounds. The 1979 cost of treatment of the excessive waste was \$0.77/kg for all four waste constituents. The formula applied to calculate the surcharge assessment, as given in Table 38, was:

$$\text{Annual Surcharge (\$)} = V \times F \times G \times C$$

where: V = annual volume of discharge in Imperial gallons,

F = Conversion factor $\frac{10}{1\,000\,000}$

G = excessive concentration of suspended solids, grease, BOD₅ or phenols in mg/L, whichever is greatest in excess of the bylaw limits,

C = cost in \$ for treating the excessive waste strength (1979 costs were \$0.035 per pound or \$0.077 per kg).

The annual savings in the basic water and sewer costs resulting from the in-plant water and waste conservation program at Prime Packers can be readily calculated from the annual reduction in water use from the baseline period to the post-modification period. The total annual reduction resulting from all modifications, according to Table 40, was 28 335 m³. At a total water and sewer cost of \$0.24/m³, the annual saving to the plant is \$6800.40. However, a fraction of the total savings was accomplished as a result of the installation of the air-cooled refrigeration system, initiated by Prime Packers Ltd. If the total reduction in water consumption is corrected for that resulting from the installation of the air cooler, an annual reduction of 20 500 m³ can be attributed to the in-plant modifications made during the demonstration project. This translates to an annual savings of \$4920. The air-cooled refrigeration system alone produced an annual saving of approximately \$1900 in water and sewer costs.

The annual saving resulting from the reduced process effluent loading is more difficult to estimate. The municipality usually samples the process effluent several times each year and the average concentration based on these samplings is used to calculate the surcharge. In the case of Prime Packers, the BOD₅ concentration is the factor used in the surcharge formula as it is consistently the greatest in excess of the bylaw limit (500 mg/L). The annual discharge volume is assumed to be 80 percent of the annual consumption, which allows a 20 percent loss to the product and evaporation.

In 1979, Prime Packers had been assessed an overstrength surcharge of approximately \$10 600. Subsequent to completion of the in-plant modifications, a reassessment of the surcharge was requested by Prime Packers. The process effluent was sampled by personnel from the municipality; however, the reduction in the surcharge has not yet been formulated. Discussions with municipal and plant personnel indicate that a reduction in the order of \$5 000 to \$6 000 could be anticipated.

As the actual reduction in sewer surcharge was not available, a theoretical reduction was calculated from the baseline and post-modification sampling and analytical results. Based on the average waste strength (BOD₅ = 2 000 mg/L) and the annual water consumption (98 329 m³), the calculated overstrength charge for the baseline plant condition is:

$$\text{Annual Surcharge (\$)} = \frac{(21\,658\,370 \times 0.8)}{100\,000} \times (1\,500 \text{ mg/L}) \times 0.035 = \$9\,906.52$$

The calculated annual surcharge is less than the actual surcharge primarily because of the different sampling techniques used by the municipal and study personnel.

The sampling conducted by the municipality is generally a composite sampling of the kill shift and the early portion of the cleanup shift. As the effluent strength from the end of the cleanup to the beginning of the subsequent kill shift is considerably lower, the municipal sampling slightly overestimates the total plant loading compared to the results obtained from a 24-hour composite sampling.

Based on the post-modification conditions at the plant (annual water consumption $69\,994\text{ m}^3$, average effluent BOD_5 1420 mg/L), the annual surcharge would be as follows:

$$\text{Annual Surcharge (\$)} = \frac{(15\,417\,180 \times 0.8)}{100\,000} \times (920\text{ mg/L}) \times 0.035 = \$3\,971.47$$

The water consumption figure used for calculation of the post-modification surcharge included the reduction associated with the installation of the air-cooled heat exchanger. This should not affect the process effluent BOD_5 loading or the calculated annual surcharge.

Based on the annual water use and the waste strength for the two periods of the study, the reduction in sewer surcharge for the Prime Packers plant resulting from the in-plant water and waste conservation program was approximately \$5125 annually. This is in agreement with the estimates made by the municipality.

The total reduction in water and sewer costs to Prime Packers resulting from the in-plant water and waste management program can be summarized as:

	Annual Savings (\$)	
	All Modifications	Excluding Air-Cooled Heat Exchanger
Water and Sewer Costs	\$ 6 800.40	\$ 4 920.00
Surcharge Assessment	<u>\$ 5 125.00</u>	<u>\$ 5 125.00</u>
Total	\$11 925.40	\$10 045.00

The total cost of the in-plant modifications was \$9221.53:

Materials	\$6 534.80
Tax	\$1 086.73
Labour	<u>\$1 600.00</u>
Total	\$9 221.53

The cost figure does not include the time invested by study personnel for flow measurement, sampling, equipment selection and in-plant observation. In addition, the costs associated with the design and installation of the air-cooled refrigeration system are not included.

Based only on the annual savings in water, sewer and surcharge costs, the pay-back period for the in-plant modifications is less than one year. Some return should also be achieved from the recovery and sale of blood despite the increased labour associated with cleaning the blood collection system. The gross annual return on the sale of blood, assuming 245 production days per year and an average recovery of 2.75 t/d, would be \$12 250. Study personnel estimated the maximum increase in labour costs due to the system in the range of \$5000. An additional \$7250 annually could then be saved. If this is the case, the total reduction in plant operating costs from the water and waste conservation program would be in the range of \$17 000 to \$19 000 annually.

4.3.9 Summary of the Water and Waste Conservation Program at Prime Packers Ltd.

The in-plant water and waste conservation program at the Prime Packers Limited meat packing plant accomplished a reduction of 20.8 percent in annual water consumption. Waste loading, in terms of the most critical parameter, BOD₅, was reduced by almost 50 percent.

The estimated economic return from the in-plant modifications was in the range of \$17 000 to \$19 000 annually based on the reduced water and sewer costs, reduced surcharge and some net return from blood recovery. Total cost of the in-plant modifications was \$9221.53.

The most significant improvement resulted from the installation of a blood recovery system. The system, installed at a cost of \$7731.40, was probably responsible for \$12 375 of the total return. Obviously, blood recovery is one of the most significant steps that should be taken in any packing plant not already practicing it.

The in-plant modifications implemented to conserve water were equally effective. Despite the relatively good water use practices in evidence at the plant during the baseline period, a reduction of more than 20 percent was accomplished in the annual consumption. The cost of these modifications was only \$1490.13. The reduction in water and sewer costs resulting from the modifications was \$4920.00. All these modifications were relatively simple, involving readily available equipment such as solenoid valves, timers and switches, and were installed by plant personnel in a total of 30 hours.

According to plant inspection staff, there was no deterioration in product quality as a result of any of the changes.

4.4 Dvorkin Meat Packers Ltd.

Dvorkin Meat Packers Ltd. is a medium-sized slaughterhouse in an industrial section of Calgary. The plant is exclusively a beef slaughterhouse, producing dressed carcasses for wholesale. There are no further processing or rendering operations.

In 1978 Dvorkin slaughtered slightly less than 110 000 head of cattle at an average dressed weight of 257 kg/head. Dvorkin normally slaughters 400-450 head per day, although day to day fluctuations are common. During the latter portion of this study the plant was only killing 300-325 head/day due to a cattle shortage.

4.4.1 Plant Description. Cattle are held briefly in uncovered pens outside the plant. They are herded into a chute where they are stunned with a handheld stunner, then suspended on the overhead rail. After severance of the jugular vein, the carcasses briefly bleed onto a curbed portion of the floor. Much of the blood drains to a collection truck to be hauled to landfill. Hooves, heads, and hides are then removed. In the course of this study, Dvorkin altered its hide-pulling operation from a manual to a mechanical hide puller. Hooves are disposed of into a chute to be hauled away. The heads are removed to a separate area for washing. Hides are dropped into a chute to the collection truck.

The carcass is split open and viscera removed. Edible viscera are flumed to the basement for processing. Inedible viscera are dropped down a chute to a collection truck. Paunch contents are wet-dumped and, until recently, paunches were disposed of along with inedible viscera. During the latter part of the study, Dvorkin began saving paunch for sale to a pet food manufacturer.

Carcasses are inspected, trimmed, washed in a high pressure oscillating spray washer, covered with shrouds, and conveyed off the kill floor to be cooled. All of Dvorkin's major operations take place in one room on the second storey of the plant. Space is somewhat limited, the facility having been constructed for a lower level of production, and the kill floor is congested. The production area is shown in Figure 36.

4.4.2 Baseline Water Use. Water use and corresponding data for production were obtained beginning November, 1978 and continuing through the first few months of 1979. The City of Calgary water meter was read most weekday mornings at 0600 hours, before the start of the production day. Occasional weekend readings were taken. For three weeks in late November and early December, 1978, the meter was read also at 1530 hours,

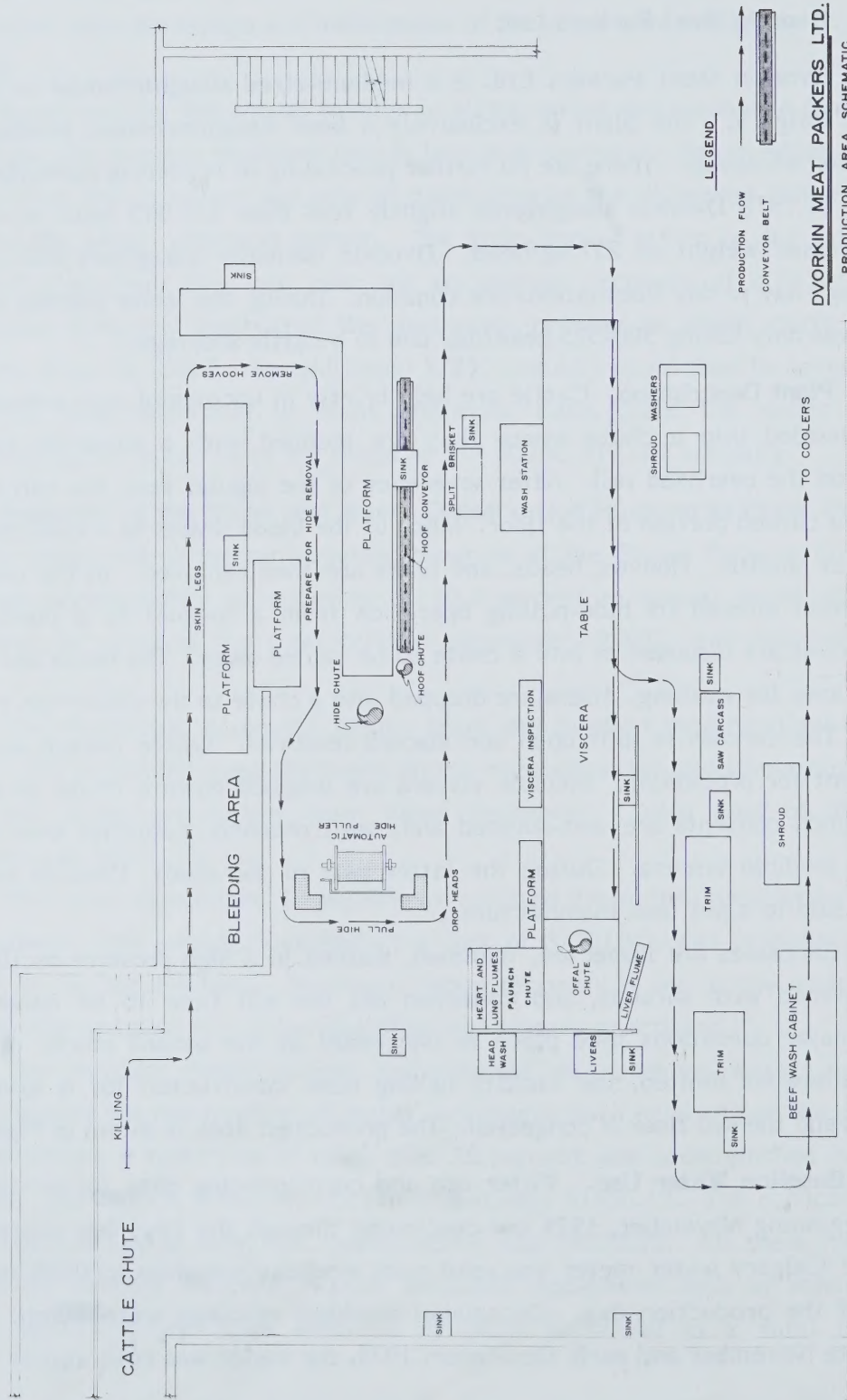


FIGURE 36 DVORKIN MEAT PACKERS LTD. PRODUCTION AREA SCHEMATIC

the end of the production shift. The plant supplied data on daily production, expressed in terms of number of head slaughtered and dressed weight.

A few water meters were installed on the kill floor, but meters were generally avoided due to the multiplicity of supply lines and inaccessibility of locations that could be readily monitored. Judgements on efficiency of water use for individual processes relied heavily on observation and discussions with plant personnel.

Table 46 summarizes the baseline water use at Dvorkin Meat Packers Ltd. Benchmark data was used to extrapolate annual equivalents.

TABLE 46 BASELINE WATER USE AT DVORKIN MEAT PACKERS LTD.

Total Water Used, November 1, 1978 - March 1, 1979	100 337	m ³
Daily Water Use		
Production Day	1 091.6	m ³
Non-Production Day	282.5	m ³
Daily Production		
Number of Animals	423	
Dressed Weight	114 504	kg
Annual Equivalent Water Use		
Total Water Use	301 342	m ³
Production Days (245 days)	267 442	m ³
Non-Production Days (120 days)	33 900	m ³
Annual Equivalent Total Production		
Number of Animals	103 635	
Dressed Weight	28 053 395	kg
Production-Based Water Use		
Production Days Only		
per Head	2 581	L
per kg Dressed Weight	9.5	L
Total		
per Head	3 249	L
per kg Dressed Weight	12.0	L

Between November 1, 1978, and March 1, 1979, average use on production days was over 1000 m³. On non-production days the plant used about 280 m³, which is an

indication of the number of leaks and broken valves in the plant. Non-production day use also includes background water consumption and a special Saturday cleanup.

Overall the plant used 3249 L/head and 12.0 L/kg dressed weight, toward the high end of the industry-wide spectrum. Non-production days contributed slightly more than 20 percent of the water use per unit product.

There was a gradual trend of increased production-day water use between November, 1978, and February, 1979. The increase, shown in Table 47, was attributed to the addition of extra nozzles to the carcass washer, and the increasing number and severity of leaks.

TABLE 47 BASELINE PRODUCTION-DAY WATER USE, DVORKIN MEAT PACKERS LTD.

Month	Production-Day Water Use (m ³)	Average Head Killed per Day
November	1 047	422
December	1 050	422
January	1 118	441
February	1 173	409

There was a strong inverse relationship between total production and water use on a per unit product basis. The relationship can be described by a straight line (obtained by least squares technique) as shown in Figure 37. The slope of the line, indicates that, for every additional head processed, water use decreases by an average of 5.01 L. For instance, if the plant kills 400 head in a day it can expect to use 2648 L/head. At a kill of 425 head, the water expenditure is 2523 L/head.

The production shift consumed an average of slightly less than 75 percent of the 24-hour water supply. Measurements taken over a 15-day period showed that an average of 276 309 L of water was used during the non-production hours of 1530 hours to 0600 hours. This can be broken down into the cleanup shift, using about 205 677 L, and overnight usage of an estimated 70 632 L.

Water use was not determined for all unit processes. Rather, observation of unit processes and discussions with plant personnel were used to identify major water consumers and potential areas for improvement.

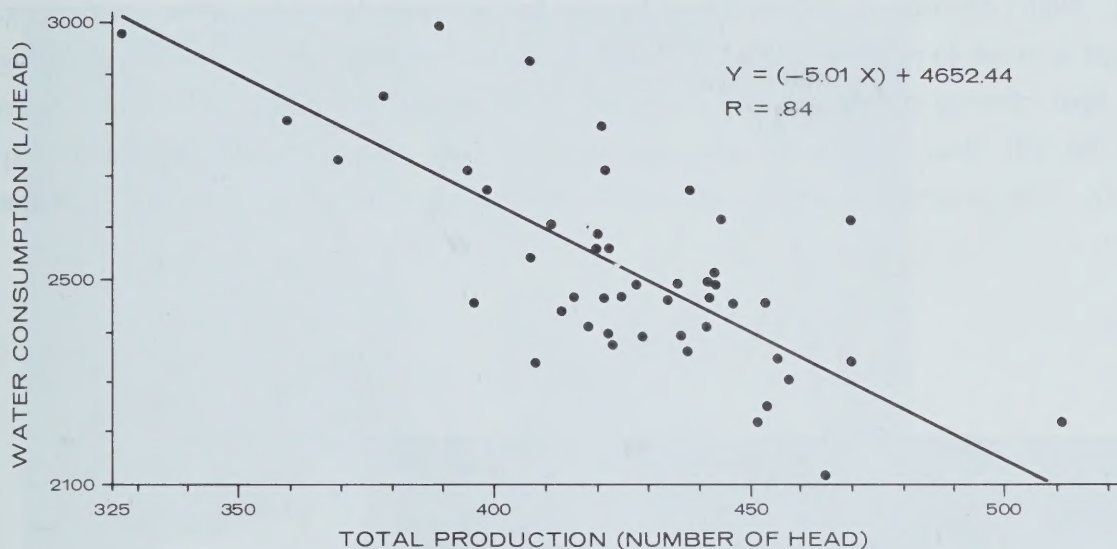


FIGURE 37 DVORKIN MEAT PACKERS LTD.: WATER USE PER UNIT PRODUCT VERSUS LEVEL OF PRODUCTION

Most processes on the kill floor do not require the direct application of water. With the exception of carcass washing, virtually all water is used for cleaning and sanitizing, e.g., washing hands and sterilizing equipment.

Holding pens are cleaned "dry", and cattle are held only a few hours.

Carcass wash. The carcass wash was undoubtedly the largest single user of water in the plant. Water usage was estimated at $591 \text{ m}^3/\text{d}$, over 50 percent of the daily water use. The oscillating spray washer has a design capacity of 65 spray nozzles. At the beginning of the study between 35 and 40 nozzles were in use. Another eight nozzles were added in January and several more in February. The washer operates at 2100 kPa.

Cleanup. Flows associated with cleaning equipment, floors and walls constituted the second largest water use in the plant. In addition to the cleanup shift, estimated at 205 677 L, spot cleaning occurs at breaks, lunchtime, and throughout the production day.

An exact determination of the volume of water used specifically for cleanup was difficult because of the many leaks. It was estimated to be 15 to 20 percent of total daily water use.

Night cleanup is accomplished by one half-time and two full-time employees. An attempt is made to remove solids "dry" before washdown with a high-pressure cleaning system. Spot cleanup during the day consisted of sweeping, shovelling, and hosing down areas of the kill floor. After a hose was used, it was often left flowing needlessly (Figure 38). On Saturday mornings students are employed to scrub down and sanitize equipment.



FIGURE 38 HOSE LEFT FLOWING ON FLOOR

The photo was taken during coffee break.

Shroud wash. Shrouds were being washed throughout the production day in two large industrial washing machines. The machines were worn and damaged. Although they operated well enough to clean shrouds satisfactorily, they leaked continuously and profusely (Figure 39). The water consumption of the shroud washers was not precisely

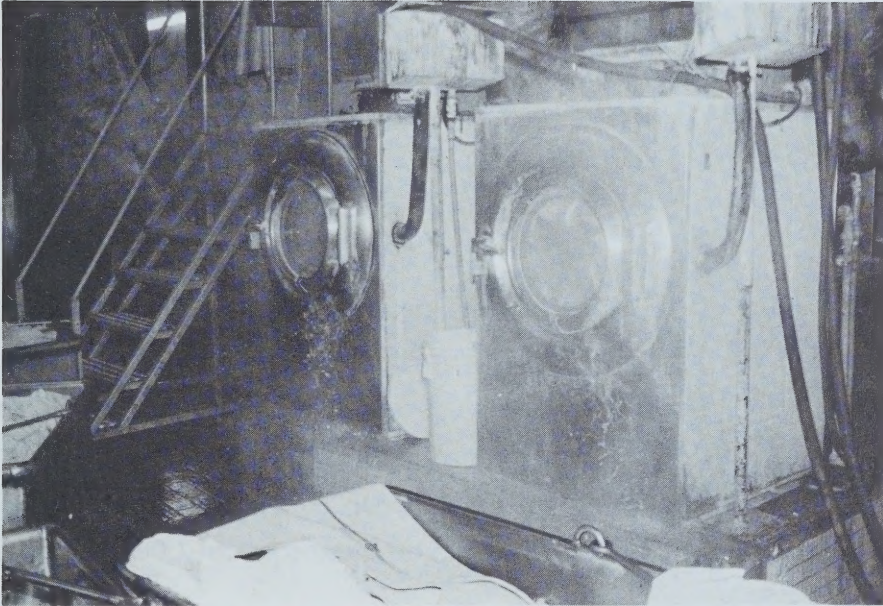


FIGURE 39 SHROUD WASHERS

determined, but it was believed to constitute a substantial proportion of the daily water use.

Employee wash stations. Most of the water used on the kill floor was for washing hands and arms, and rinsing and sterilizing knives and saws. There were 17 sinks on the kill floor, and several had knife sterilizers and/or drinking fountains attached to the sides. A few of the sinks were rarely, if ever, used. The sinks were equipped with foot operated control valves, which were mostly inoperative. Many had been broken or jammed open by employees. Some sinks flowed 24 hours a day; others leaked profusely, even when turned "off". Drains in the sinks were plugged, and continuously overflowed their brims (Figure 40). This allowed employees to wash their hands and arms by immersion, which they found a quick and thorough washing method. Observation indicated that employees only immersed their hands and arms in the basins once every three to five minutes.

A meter was installed on one sink, and the flow averaged 4078 L/d. There were 15 sinks flowing at various uncontrolled rates. The total flow through the

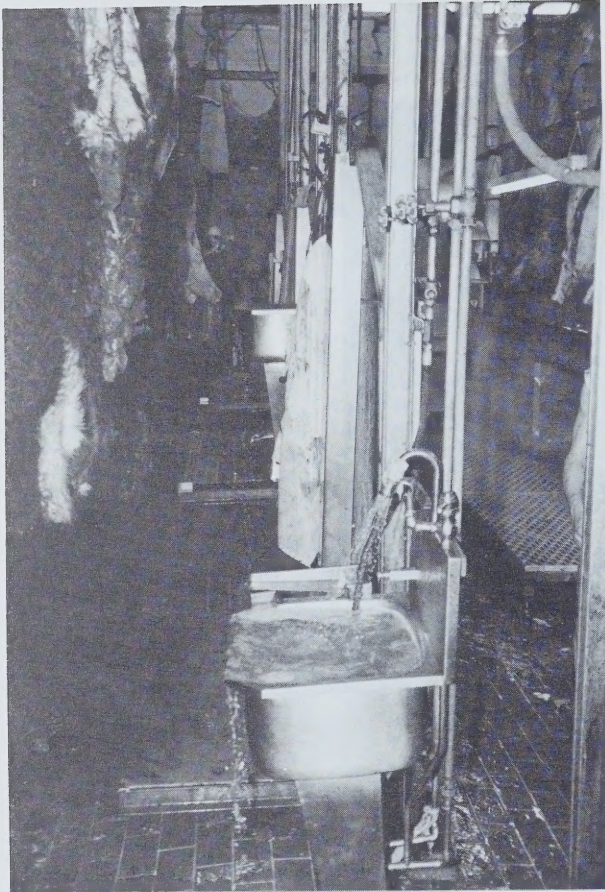


FIGURE 40 EMPLOYEE WASH SINK

uncontrolled sinks was estimated at 61 000 L/production day, or 5.6 percent of the daily water use.

One sink, equipped with a showerhead nozzle, was monitored for comparison with the uncontrolled sinks. Daily flow averaged 2432 L, about 40 percent less than the sinks without nozzles. Another sink, with an operative foot control, was metered at 1814 L/d, less than half the flow of the uncontrolled sinks.

Another wash station, a free-standing spray on the brisket-splitter's platform, also used a foot-controlled valve. It was not metered, but obviously used less water than the uncontrolled sinks.

Additional cleanup facilities included a semi-enclosed employee wash station on the kill floor and complete showers. In total, employee wash-up and knife and saw cleansing was estimated at 10 percent of the daily plant water use.

Leaks and open valves. Water lost to sewer from leaks and valves left open was excessive. It was not uncommon to observe sinks, hoses, washing apparatus, and other water-using equipment flowing during breaks, lunch and after the production shift. Visits to the plant late at night revealed water flowing steadily through the majority of taps, whether or not they were shut "off".

Viscera table wash. The stainless steel viscera table was continuously cleaned as it moved in conveyor belt fashion. First, it was sprayed with hot water and steam to clean and sterilize; then with cold water to cool and rinse it. The cold water spray was applied through two pipes, one with nozzles and the other a drilled pipe.

Viscera table rinsing and cooling used 120 L of cold potable water per minute. Total daily usage varied depending on the length of time the wash flowed, but averaged about 75 000 L/d, approximately seven percent of the 24-hour water use.

Paunch dump. Water was required both to quickly empty the paunch of its contents and to facilitate the flow of paunch manure through a pipe to screening. Total water used for the wet dump of the paunch and transport of the manure was measured at a maximum of 8100 L/h, equivalent to approximately 65 000 L/d.

Head and edible viscera handling. Heads were washed manually, using an undetermined volume of potable water. The head washer was not considered in this study because Dvorkin had already arranged for use of a Chad automatic head washer in the near future.

Water was used to flume hearts, livers, lungs, and kidneys to an area in the basement for trimming, cooling and packaging. The flumes had a steep slope and used minimal water. However, leaking valves caused water to flow through the flumes constantly, even when not in use.

4.4.3 Baseline Waste Loads. All individual effluent streams at Dvorkin Meat Packers ultimately flow together into a catch basin, and from there are pumped into a dissolved air flotation cell. After treatment by dissolved air flotation, the wastewater flows into the municipal sewer. The unit was installed when daily slaughter levels were lower. Its design capacity is exceeded when the plant slaughters in its normal 350-450 head per day range.

Several floor drains in the blood collection and hide-pulling areas flowed into a blood collection tank with two potential outlets. The valving may be set so that blood flows into a collection truck to be hauled away, or it may be set to allow flow into the effluent catch basin prior to the air flotation cell.

Other floor drain waste streams flow through a rotary screen before going to the common catch basin. Solids are sent to the renderer's collection truck. Paunch contents are screened separately and the recovered solids are saved to be hauled away.

There are separate disposal chutes from the kill floor to collection tanks in the basement for large solids, such as viscera, hooves, and hides. The chutes are vertical and do not require transport water.

During the past few years, the strength of effluent discharged from Dvorkin to the municipal system has routinely exceeded the City of Calgary concentration limits. At the beginning of this study the plant was paying a surcharge for exceeding the BOD₅ limit of 300 mg/L by 818 mg/L, and oil and grease limit of 100 mg/L by 76 mg/L. The suspended solids level was within the 300 mg/L limit. In previous billing periods, Dvorkin had generally been assessed surcharges based on even stronger concentrations.

Table 48 shows final effluent concentrations measured during the production shift at Dvorkin. Suspended solids levels tended to stay close to the municipal surcharge limits, and were more consistent than the BOD₅ and oil and grease parameters. Because of the skewed distributions of the samples of BOD₅ and oil and grease, the median is a more meaningful measure than the mean. The pollutant concentrations were generally consistent with those measured by the municipality in the previous year and a half.

Table 49 shows the results of cleanup shift effluent sampling. Table 50 converts the data into daily and production-based loading data. The values are slightly overestimated, as the cleanup shift concentrations were applied to all non-production shift water flows. The loadings between the cleanup shifts end and the next day's production shift would actually be lower than those used in the calculations.

Except for suspended solids, the production-based loadings were above the industry average. The absence of a concerted in-production waste management program contributed to the relatively high waste loadings at Dvorkin Meat Packers Ltd. There was little effort to prevent wastes from entering the sewers, and blood and solids mixed with wastewater streams, exerting heavy removal demands on the screening and air flotation systems.

Blood accumulated on the floor from the point where the cattle were stuck through the hide pulling, hoof removal, and head removal process areas. Obviously, the

TABLE 48 BASELINE PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, DVORKIN MEAT PACKERS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
Nov. 28/79	1 093	322	-	105
Nov. 29/79	1 142	243	-	248
Feb. 2/79	480	420	129.5	379
Feb. 11/79	4 500	287	-	3 252
Feb. 14/79	1 560	350	63	449
Mean	1 755	324	96	887
Median	1 142	322	-	379
City of Calgary Surcharge Limitations	300	300	-	100

TABLE 49 BASELINE CLEANUP SHIFT PROCESS EFFLUENT CHARACTERISTICS, DVORKIN MEAT PACKERS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil and Grease (mg/L)
Feb. 2/79	529	237	102.5	232
Feb. 13/79	2 040	216	-	726.5
Feb. 14/79	382	100	244	124
Mean	984	184	173	361

greatest volume of blood accumulated in the earliest stages following the kill. The floor in that first area was partially curbed off from the rest of the kill floor; however, the curbing did not completely segregate blood from other waste streams.

Water from the overflowing wash sinks flowed through blood accumulations, dissolving them and carrying them to the floor drains (Figure 41). Two of the floor drains in the immediate vicinity of heavy accumulation did not flow to the blood collection tank, but to a rotary screen. Thus some blood entered the plant's sewer system directly.

Much of the blood which flowed through drains to the collection tank was also ultimately rerouted to the sewer rather than being hauled away. Dvorkin had found no

TABLE 50 BASELINE WASTE LOADINGS, DVORKIN MEAT PACKERS LTD.

	BOD ₅	Suspended Solids	Total Kjeldahl Nitrogen	Oil & Grease
Production-Day Loadings (kg)				
Production Shift	931**	264	78	309**
Non-Production Shift*	<u>272</u>	<u>51</u>	<u>48</u>	<u>100</u>
Total Day	1 203	315	126	409
Production-Based Loadings (kg/1000 kg dressed weight)				
Production Shift	8.1	2.3	0.7	2.7
Non-Production Shift*	<u>2.4</u>	<u>0.5</u>	<u>0.4</u>	<u>0.9</u>
Total	10.5	2.8	1.1	3.6

* "Non-Production shift" includes cleanup shift average concentrations applied to non-production shift (cleanup plus maintenance) flows.

** Median concentrations used for calculations. All other calculations relied on mean concentrations.

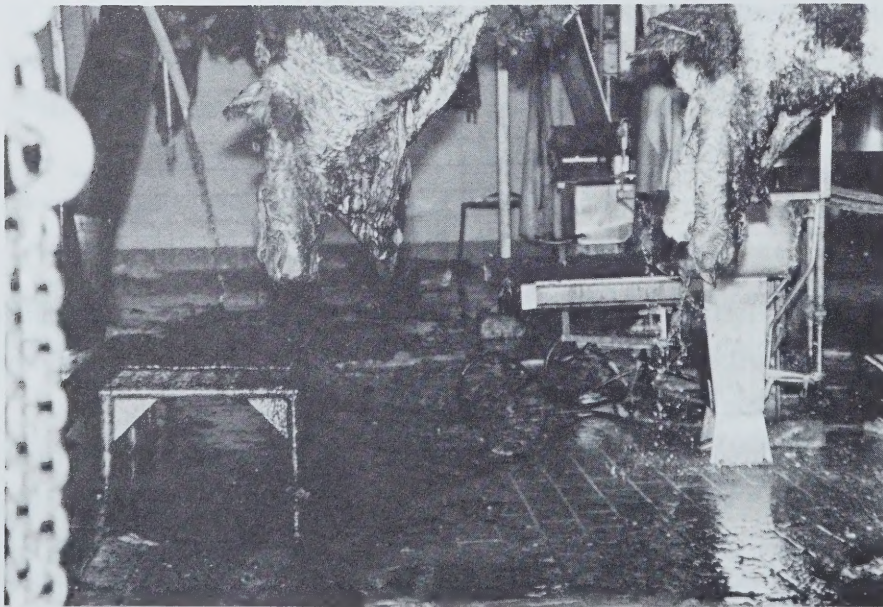


FIGURE 41 WATER AND BLOOD MIXING ON KILL FLOOR

market for collected blood, and had to pay to have it hauled away. The tank in which the blood was trucked away generally was full by mid-shift because some floor drains leading to it were receiving waste streams heavily diluted with overflows from the wash sinks. At that point, valves were switched to send collectable blood to the sewer until the truck tank was hauled away, dumped, and returned.

During lunch and coffee breaks and after the production shift, an effort was made to squeegee congealed blood into drains to the collection tank. Then the area was hosed down. In an attempt to conserve space in the tank, the bloody rinse water was sent to the sewer rather than the tank. A grab sample of the effluent taken during the morning coffee break had a BOD₅ of nearly 3000 mg/L.

Chutes, troughing, and containers were available to dispose of most solids trimmed from carcasses along the production line. However, in many cases staff found them difficult to use. For instance, hooves were dropped into a narrow trough from the high platform and consequently accumulated on the floor. Solids also accumulated on the floor at the trim station. Although troughing was provided, it was narrow and scraps often fell onto the floor rather than into the trough (Figure 42). Solids occasionally clogged the drain gratings and water would pool. This situation certainly contributed to the high waste loadings experienced.



FIGURE 42 SOLIDS ON THE FLOOR NEAR THE TRIM STATION

The photo was taken during a break. The employee at the far right is shovelling up the accumulated scraps.

Wet dumping the paunch is recognized as a strong contributor to plant effluent loading (see Appendix A). A grab sample of screened paunch dump water revealed high suspended solids and oil and grease loadings (1306 mg/l and 1131 mg/L, respectively).

The automatic carcass washer affected plant waste loads in two ways. The high-pressure wash removed fat and small solids, which increased the total effluent loadings beyond those caused by a manual carcass washer. On the other hand, the extremely large volumes diluted the plant effluent, and therefore weakened concentrations of pollutants.

4.4.4 Plant Attitudes. Shortly before the beginning of this study, new owners assumed Dvorkin's management. The plant was undersized, some of its equipment was outdated, and it had suffered from inadequate maintenance. The work force was young and inexperienced. The new owners were in the process of upgrading the plant.

The carcass washer was newly installed when the study began. It had required the addition of a larger municipal water supply line before it could be used. An automatic hide puller and a new chill tunnel were being installed throughout the study period. The hide puller required major kill floor modifications. After installation of the hide puller the plant intended to put in an automatic head washer.

Management was well aware of the need for water conservation and waste reduction. However, with several major projects underway, water and wastewater management necessarily took a lower priority. Obtaining labour for weekend work on these major projects week after week was difficult, and men simply could not be spared for such routine maintenance tasks as repairing leaky valves.

This was particularly true considering that several sinks and other water outlets would be moved or removed in the course of the planned kill floor modifications. Management was improving the plant carefully and systematically. Its plans were to improve water and waste management practices after the general layout and equipment on the kill floor were settled and complete.

There were some concerns about the cooperation that could be expected from the labour force in improving water and waste management practices. In contrast to the established professional European butchers at Prime Packers Ltd., the kill floor staff at Dvorkin was young and inexperienced and, for the most part, without the dedication and professionalism of the Prime Packers staff. Several of the workers were given to "clowning" on the job, and seemed to view themselves in an adversary relationship with management.

Concern about the labour force limited the modifications that could be accomplished. For instance, study personnel proposed repair of the foot-operated valves on wash sinks, but plant management cautioned that the sinks would likely be broken again in a short time unless they were of extremely heavy-duty materials and construction. At one time the plant attempted to equip some sinks with showerhead nozzles, most of which rapidly disappeared or were broken. Therefore management recommended against installing nozzles on sink goosenecks or on cleanup hoses.

Another reason that water conservation and waste reduction were not high management priorities related to the recent changes at the plant. The plant was accustomed to relatively low water costs and also low sewerage costs (since municipal sewerage charges and overstrength surcharges are levied on a per cubic metre basis). However, the new carcass washer and larger water supply line were to mean greatly increased water and sewerage costs. In fact, conservation had not become an economic imperative until about the time that this study began.

The plant management assumed an interested and cooperative attitude toward the study. The plant superintendent assisted in data collection, worked with study personnel on designing modifications, and took the initiative on several improvements.

The Agriculture Canada veterinarian-in-charge took an active interest in the goals of the study, and provided input on the relationship of proposed changes to product wholesomeness.

4.4.5 Modifications. Modifications were implemented in March and April of 1979. The following subsections describe the in-plant modifications and evaluate their effect.

Wet Paunch Dump. The paunch was not being saved for tripe. Therefore, potable water was not necessary in the wet dump procedure.

Spent carcass wash water was recycled to the paunch dump to eliminate the need for potable water. A 1.2 x 2.4 m galvanized catch basin was fabricated and installed in the bottom of the carcass wash cabinet. An air operated diaphragm pump capable of pumping 364 L/min at a pressure of 11.6 kPa conveyed the water through PVC pipe to the paunch dump. A screen on the inlet line prevented large chunks of fat from entering the recycle line.

The cost of these modifications was:

Materials

Collection Basin

\$ 426.80

Watts Air Vacuum Pump, Model SB1 1/2-8	\$ 858.95
Collection Basin Cover & Screen	\$ 137.44
Pipe, Fittings and Miscellaneous Materials	\$ <u>141.77</u>
Sub-total	\$1 564.96

Labour

12 hours @ \$22/hour	\$ 264.00
8.5 hours @ \$38/hour	\$ <u>323.00</u>
Sub-total	\$ <u>587.00</u>
Total	\$2 151.96

The labour costs reflect charges for fabrication and plumbing by non-plant, non-study personnel.

When the system was about to be installed, Dvorkin contracted to sell paunch, not as tripe for human consumption, but for use in pet food. Veterinarians at the regional Health of Animals Branch Office were consulted. Their opinion was that there would be no harmful effect from using spent carcass wash water for the initial paunch dump.

The system virtually eliminated the need for potable water input for the paunch dump, saving up to 65 000 L of water per day. However, after the project was completed, the plant reported that it had abandoned the system. The main reason was the heavy demand placed on the air compressors, which the plant had not anticipated. A simple centrifugal pump would have been adequate and would not have been susceptible to the problem of lack of air supply.

Viscera table wash. The drilled pipe spray to rinse and cool the eviscerating conveyor table applied water inefficiently.

The drilled pipe was replaced by a copper line with seven nozzles rated at 0.64 L/min each. The nozzles provided a flat jet spray which overlapped to cover the table efficiently (Figure 43).

These modifications cost:

Materials

Nozzles	\$ 8.05
Pipe and Fittings	\$ <u>4.25</u>
Sub-total	\$ 12.30



FIGURE 43 VISCERA TABLE WASH

Labour

1 hour @ \$10/hour	\$ 10.00
Total	\$ 22.30

Water use was cut 45 percent, from an average of 74 701 L/d to 41 155 L/d. Achievable water use was shown to be as low as 27 000 L/d, when care was exercised to turn the system off during breaks and after the day's production ceased.

Handwash sinks. The sinks flowed at varying rates, some as high as 17 L/min. They overflowed continually, mixing with blood and solids on the floor and carrying these pollutants to floor drains.

Flow controls preset at 4.5 L/min or less were installed on goosenecks to reduce the fresh water input to the wash sinks. Sink drains were installed about 2 inches below the brims of the sinks, with 1-inch PVC pipe directing the overflow directly to floor drains.

The cost was:

Materials

11 flow controls @ \$4.64	\$ 51.04
Piping, fittings, strainers	\$ 154.84

	Sub-total	\$ 205.89
<u>Labour</u>		
11 hours @ \$38/hour		\$ 418.00
2 hours @ \$22/hour		\$ <u>44.00</u>
	Sub-total	\$ 462.00
	Total	\$ 667.89

The labour costs reflect charges of plumbing personnel rather than plant or study personnel.

After discussion with plant personnel and some experimentation, the decision was made to temporarily continue the method of immersion handwashing. Nozzles produced too small a flow for a quick thorough handwash, and showerheads were apt to be removed. Demand activated valves were vulnerable to jamming by employees who preferred the immersion technique.

Dole flow controls (Eaton Corporation, Controls Division, Carol Stream, IL) regulated the flow through the goosenecks at a maximum of 4.5 L/min or less. Water use was further reduced by the removal of several sinks with the addition of the new hide puller. Achievable water use in an eight-hour production day was calculated at less than 24 000 L (11 sinks at 4.5 L/min). However, it was estimated that actual water use was somewhat higher due to remaining leaks and the tendency of employees not to turn sinks off at breaks and after the production shift.

The installation of overflow drains on wash sinks allowed immersion hand washing to continue temporarily without water falling to the floor. The modification allowed the overflow to be directed to floor drains rather than mixing with other waste streams and taking blood and solids to the sewer. Shortly after completion of this study, demand controls were installed and immersion handwashing was discontinued.

Blood collection. Blood was being unnecessarily lost to sewer in three ways. First, the overflow from handwash sinks mingled with blood accumulations, dissolving the blood and carrying it to sewer. Second, when the truck tank was full, blood was sent directly to sewer while the tank was picked up, taken to landfill, emptied, and returned to the plant. Third, during hosedowns of the blood collection area the bloody wash water was sent to the sewer to avoid overflowing the truck tank.

The modifications to sink overflows described above alleviated the mixing of blood with wastewater. Some sewer drain lines that had carried a rather dilute mixture of blood and wastewater to collection were routed to the sewer system.

Two drain caps were made to cover floor drains. They could be used to prevent concentrated waste streams from flowing into the sewerage system, or to prevent dilute waste streams from flowing into the blood collection system.

Dvorkin contracted with its hauler to bring a second truck tank each day so that blood could be collected without major interruption. Finally, cleanup of the blood collection area was modified to save more blood. Squeegees were used to send as much blood as possible to the collection tank. Then the area was sprayed with a minimal amount of water, which also was sent to the collection tank. The introduction of a second truck tank made it possible to save small amounts of water-blood mixture without straining collection capacity. Finally, the drain caps were switched - drains to the sewer system were uncovered and those to the blood collection tank were capped - and the area was rinsed for a second time.

The cost of the two drain caps at \$5.00 each was negligible. The plant absorbed the cost of a second daily truck tank haul, which was \$35 per day. After a month and a half, the plant altered its sewer piping so that the second daily haul was no longer needed. Dvorkin initiated and paid for the cost of modifying the sewer piping.

Blood going to the sewer system was reduced dramatically. The reduction contributed to substantially lower effluent loadings (see Section 4.4.7).

An attempt was made to find a market for Dvorkin's collected blood, but none could be located. The only local blood drying facilities belonged to competing slaughterhouses, and all were utilizing their facilities to the maximum. Dvorkin was making plans to centrifuge the blood and save plasma, but in the meantime had to continue to pay to have its blood trucked to landfill.

When the more dilute blood/water lines to the blood collection tank were eliminated, the second daily truck tank was no longer necessary. Only floor drains in the area of heaviest blood accumulation flowed to the tank. Elimination of one of the loads of blood to be hauled away daily saved \$35/day, but some of the floor drains no longer flowing to the collection tank now carried dissolved blood to the sewage system. Dvorkin's future plans included the installation of drip troughing to catch blood between the blood collection area and the viscera table to further reduce the blood flowing to the sewer system.

Plant-initiated modifications. Concurrent with this study, Dvorkin made several alterations on its own that affected water usage and effluent loadings.

The plant added improved chutes and troughing to remove inedible trimmings from the kill floor. The net effect was fewer waste materials on the floor and, consequently, fewer finding their way to the sewer. Further improvements are part of the plant's future plans.

Because Dvorkin began saving paunch for sale to a pet food manufacturer, an added water use, tripe washing, emerged during the study.

Lungs are also being saved for use in pet food. The plant has fashioned a spray cooling system to chill the lungs. The plant superintendent estimated that the system used a maximum of 45 000 - 55 000 L/d.

Dvorkin acquired a new laundry machine to wash shrouds, as well as employee coveralls and aprons. The old, leaking shroud washers were eliminated and water waste reduced; however, washing employee work clothes was a new water use.

As mentioned above, Dvorkin was able to remove six wash sinks after the labour-saving hide puller was installed. Foot control valves were added to the high usage sinks, and the practice of immersion hand washing was discontinued. Installation of the hide puller meant cleaner dressing procedures. Therefore, high volumes of water in the carcass wash were no longer needed. Thirty nozzles were removed and the direction of spray from the remaining nozzles was improved.

Dvorkin installed a new refrigeration system which utilized a recycle water system with minimal makeup. The previous system had required continuous input of makeup water.

The plant instituted an improved maintenance program. For instance, as wash-up sinks were modified, leaking valves were repaired. Similarly, leaks in the edible viscera flumes were eliminated.

4.4.6 Effect of Modifications on Water Use. Dvorkin's post-modification water use was monitored between April 16 and July 30, 1979. Between April 16 and May 31, daily meter readings were generally taken. After that, meter readings were taken only occasionally.

During the post-modification monitoring period, plant-initiated modifications were still occurring. For instance, the new refrigeration system was installed in early May. The new laundry began operation at the beginning of July. Therefore, water use during the period changed and the averages presented may not be entirely accurate estimates of future water use. It is believed that they may over-estimate future water consumption.

Water use before and after the modifications are compared in Table 51. Extrapolation of the baseline and post-modification water use data to a hypothetical year comprising 245 production days and 120 non-production days yields a measure of the projected water savings on a yearly basis:

	Baseline Year	Post-modification Year
Annual consumption (m ³)	301 342	216 171
Equivalent Daily consumption (m ³)	825.6	592.2

TABLE 51 COMPARISON OF BASELINE AND POST-MODIFICATION WATER USE, DVORKIN MEAT PACKERS LTD.

	Baseline Period (Nov. 1, 1978 - Mar. 1, 1979)	Post-Modification Period (April 16, 1979 - July 30, 1979)
Total Water Use	100 337 m ³	63 746 m ³
Daily Water Use		
Production-Day Use	1 091.6 m ³	787.9 m ³
Non-Production Day Use	282.5 m ³	192.8 m ³
Daily Production		
Number of Animals	423	305
Dressed Weight	114 504 kg	80 370 kg
Production-Based Water Use*		
Production Days Only		
Per Head	2 581 L	2 583 L
Per kg Dressed Weight	9.5 L	9.8 L
Total		
Per Head	3 249 L	3 215 L
Per kg Dressed Weight	12.0 L	12.2 L
Equivalent Annual Consumption	301 342 m ³	216 171.5 m ³

* The figures shown for the post-modification period tend to be misleading. As explained in Section 4.4.6 and shown Figure 44, the production-based water use in the post-modification period would have been 541 L/head greater if water management practices had not been modified, due to the relatively inefficient use of water at such low levels of production.

The estimated total reduction in water usage was 28.3 percent on an annual basis. This is likely to be an underestimate, because water use decreased over the post-modification period. Within the latter phase of the period, May 30 to July 30, daily meter readings were not taken. However, the overall equivalent daily water use (dividing total water use by the number of days in the period) was 553.9 m^3 , compared to 834.4 m^3 during an identical period, in terms of production/non-production days, in the baseline period. Thus, the savings on a hypothetical annual basis, using the May 30 to July 30 period, would be 33.6 percent.

It was not possible to determine the distribution of the annual water savings by unit process modification. Changes in the plant often occurred concurrently and were not monitored with process meters.

Daily water consumption data was taken in May, 1979. The average usage on production days was 787.9 m^3 , a 27.8 percent decrease from the baseline period. Again, it is likely that an even greater decrease was achieved later on as the plant continued to upgrade its facilities. The production-day water use in the post-modification period was not broken down by shift.

Non-production day water use was reduced by a larger percentage than was production-day use. The decrease of 89.7 m^3 per non-production day, a 31.8 percent reduction, is primarily attributable to improved maintenance.

The baseline and post-modification monitoring periods differed substantially in terms of daily production. Post-modification slaughter rates were only about 75 percent of baseline rates. As water use per unit product increases as production levels decrease, water use per head or per kilogram dressed weight during the two monitoring periods cannot be compared directly. To derive a meaningful estimate of water savings per head due to the improved water management practice, estimates of water use per unit product under the baseline water management practices, but at lower production levels, were made using the equation for the "least squares" line described in Section 4.2.2 and shown in Figure 37.

The least squares line graphically describes the trend toward relative inefficiency of water use at low production levels.* Average daily kill during the post-

*The main reason for the inefficiency is that, when the plant slaughters fewer animals, it slows down the production line. Although fewer cattle are slaughtered in any given time, major water users, such as handwashing facilities, the carcass washer, and the shroud washer, flow at about the same rates as when production is high.

modification monitoring period was 305 head/day. Using the equation for the least squares line reveals that, if 305 head/day had been slaughtered under the baseline water management practices, the plant would have used about 3124 L/head under typical conditions:

$$\text{L/head} = (-5.01)(305) + 4652.44 = 3124.39$$

Figure 44 illustrates this graphically.

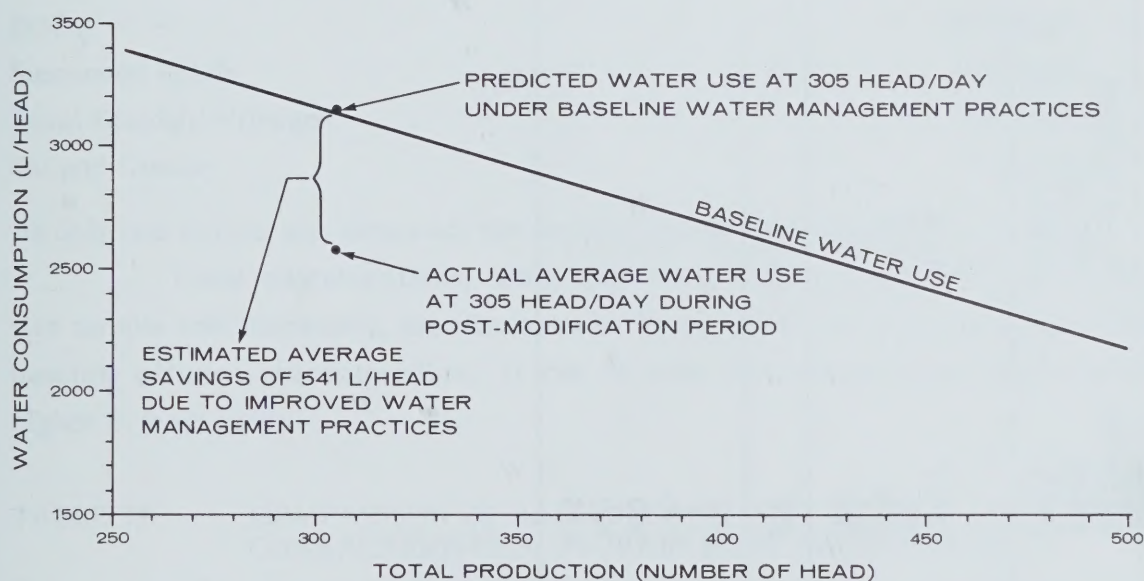


FIGURE 44 DVORKIN MEAT PACKERS LTD.: WATER SAVINGS PER UNIT PRODUCT

Average production-based water use in the post-modification period was 2583 L/head. As this figure is 541 L/head less than the estimated usage under comparable production levels during the baseline period ($3124 - 2583 = 541$), significant water savings per unit product can be attributed to the improved water management practices.

4.4.7 Effect of Modifications on Waste Loads. Table 52 displays the results of production shift effluent sampling in the post-modification period. A malfunctioning composite sampling device severely curtailed the sampling program. Four usable composite samples were obtained. Table 52 also displays the results of four grab samples taken during the production shift by Dvorkin personnel. The grab samples were relatively consistent with the composite samples, with the exception of suspended solids, which were

TABLE 52 POST-MODIFICATION PRODUCTION SHIFT PROCESS EFFLUENT CHARACTERISTICS, DVORKIN MEAT PACKERS LTD.

Sampling Date	BOD ₅ (mg/L)	Suspended Solids (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Oil & Grease (mg/L)
Composite Samples				
April 25/79	725	166.7	61.6	84.4
April 26/79	885	200	62.7	68.4
June 13/79	576	339	-	117
June 14/79	544	324	-	112
Average	682	257	62	110
Grab Samples				
June 27/79, 1100 hours	401	220	-	124
June 28/79, 1100 hours	482	360	-	100
June 25/79, 1530 hours	788	500	-	116
July 26/79, 1545 hours	741	438	-	110

generally more concentrated in the grab samples taken at 1530 and 1545 hours. Although the reason for this discrepancy is uncertain, it has been suggested that the high values of these samples reflect a "worst case" condition, as they were obtained at the end of the production shift when waste loads from the kill floor are great due to the day's accumulation.

Because of the malfunctioning composite sampling device, only one usable composite sample was obtained for the cleanup shift. Analysis of the sample yielded the following concentrations:

BOD ₅	645 mg/L
Suspended Solids	433 mg/L
Total Kjeldahl Nitrogen	246 mg/L
Oil and Grease	72 mg/L

As only one sample was obtained, the results must be interpreted with caution.

These concentrations, along with the averages of the production shift composite sample concentrations, are displayed in Table 53, where they are compared with the baseline effluent characteristics. It can be seen that the baseline concentrations were higher in most cases.

TABLE 53 COMPARISON OF BASELINE AND POST-MODIFICATION EFFLUENT CHARACTERISTICS, DVORKIN MEAT PACKERS LTD.

	Baseline Period (mg/L)	Post-Modification Period (mg/L)
Total Shift		
BOD ₅	1 142*	682
Suspended Solids	324	257
Total Kjeldahl Nitrogen	96	62
Oil and Grease	379*	110
Cleanup		
BOD ₅	984	645
Suspended Solids	184	433
Total Kjeldahl Nitrogen	173	246
Oil and Grease	361	72

* Median rather than mean.

The concentrations shown in Table 53 are expressed as total production-day waste loads in Table 54. To compute the waste loadings, it was assumed that production-shift water use accounted for 75 percent of the 24-hour water usage. "Non-production shift" waste loadings were derived by applying cleanup shift effluent concentrations to water used during the cleanup and maintenance shifts.

TABLE 54 BASELINE AND POST-MODIFICATION PRODUCTION-DAY WASTE LOADINGS, DVORKIN MEAT PACKERS LTD.

	Baseline Period (kg/d)	Post-Modification Period (kg/d)
BOD ₅		
Production Shift	931	403
Non-Production Shift	<u>272</u>	<u>127</u>
Total	1 203	530
Suspended Solids		
Production Shift	264	152
Non-Production Shift	<u>51</u>	<u>85</u>
Total	315	237
Total Kjeldahl Nitrogen		
Production Shift	78	37
Non-Production Shift	<u>48</u>	<u>48</u>
Total	126	85
Oil & Grease		
Production Shift	309	65
Non-Production Shift	<u>100</u>	<u>14</u>
Total	409	79

Because the previously noted difference in the slaughter rates during the two monitoring periods prevented direct comparison of the daily waste loadings, waste loadings expressed in terms of kilograms of waste load per thousand kilograms dressed weight of product are compared in Table 55. The figures indicated that production-shift

TABLE 55 COMPARISON OF BASELINE AND POST-MODIFICATION
PRODUCTION-BASED WASTE LOADINGS, DVORKIN MEAT PACKERS
LTD.

	Baseline Period	Post-Modification Period (kg/1000 kg dressed weight)
BOD ₅		
Production Shift	8.1	5.0
Non-Production Shift	<u>2.4</u>	<u>1.6</u>
Total	10.5	6.6
Suspended Solids		
Production Shift	2.3	1.9
Non-Production Shift	<u>0.5</u>	<u>1.0</u>
Total	2.8	2.9
Total Kjeldahl Nitrogen		
Production Shift	0.7	0.5
Non-Production Shift	<u>0.4</u>	<u>0.6</u>
Total	1.1	1.1
Oil & Grease		
Production Shift	2.7	0.8
Non-Production Shift	<u>0.9</u>	<u>0.2</u>
Total	3.6	1.0

waste loadings of BOD₅, suspended solids, oil and grease, and total Kjeldahl nitrogen were reduced. The improvements can be attributed to the improved blood collection and waste handling practices implemented at the plant.

Non-production shift production-based waste loadings showed an improvement in BOD₅ and oil and grease, but showed a deterioration in suspended solids and total Kjeldahl nitrogen. However, little confidence can be placed in these results because the non-production shift waste loading calculations were based on only one composite sample of cleanup shift effluent.

4.4.8 Economic Implications. Dvorkin Meat Packers are assessed a monthly water and sewerage charge by the City of Calgary. In addition, a surcharge may be assessed at a rate based on pollutant concentrations and levied on the water used.

Dvorkin is charged \$275.25 for the first 2273 m³ (500 000 lgal), and \$0.0911 for each additional cubic metre per month (or \$0.41/1000 lgal). The monthly sewer service charge is equal to 80 percent of the total water bill.

An overstrength surcharge is assessed based on the formula:

$$R = 0.0112B + 0.0125S + 0.0129G$$

where: R = the surcharge rate, in cents per cubic metre,
 B = mg/L BOD₅ over 300 mg/L,
 S = mg/L suspended solids over 300 mg/L,
 G = mg/L oil and grease over 100 mg/L.

The surcharge rate applies for a minimum of three months and is levied on the total water consumption.

Hypothetical monthly water and sewerage costs were calculated using the baseline and post-modification data. The figures are shown in Table 56. Production shift wastewater concentrations were used to calculate the hypothetical surcharge, because the city collects its samples within that time period.

Using the figures in Table 56, the annual savings would be \$44 595.12. However, this figure is deceptively large. Plant throughput in the hypothetical post-modification year is about 25 percent less than during the baseline year. Furthermore, much of the projected savings can be attributed to changes undertaken by the plant rather than by this study. Most of the plant-initiated modifications were not intended primarily to save water or reduce waste loadings. For instance, the hidepuller, which allowed removal of 30 carcass washer nozzles and six sinks, was installed because it saves labour, not because it would save water.

The demonstration project cost \$2852.15, excluding the time invested by study personnel and the costs of metering and wastewater sampling. Based on discussions between study and plant personnel, an order-of-magnitude estimate was made of savings attributable to the demonstration project. It was estimated that water use savings that can be attributed to the demonstration project average about one-third of the total savings achieved during the post-modification monitoring period. Most of the reduction in

TABLE 56 HYPOTHETICAL MONTHLY WATER AND SEWERAGE COSTS FOR
BASELINE AND POST-MODIFICATION MONITORING PERIODS

	Baseline Period	Post-Modification Period
Average Monthly Water Use	25 112 m ³	18 014 m ³
Monthly Water Cost	\$2 355.88	\$ 1 709.26
Monthly Sewerage Cost	\$1 884.70	\$ 1 367.40
Surcharge Rate		
BOD ₅ - 300 mg/L	842 mg/L	382.5 mg/L
Suspended Solids - 300 mg/L	24 mg/L	0 mg/L
Oil & Grease - 100 mg/L	279 mg/L	10 mg/L
R (¢/m ³)	13.3295 ¢/m ³	4.413 ¢/m ³
Monthly Surcharge	\$3 347.30	\$ 794.96
Total Monthly Cost (Water + Sewer + Surcharge)	\$7 587.88	\$ 3 871.62
Cost per Head	\$ 0.88	\$ 0.62

the overstrength surcharge rate was attributed to the improved blood and waste handling procedures instigated by this study.

One-third of the water use reductions would equal a total annual saving of \$4 655.66 in basic water and sewer service charges by the City of Calgary. One-third of the annual total surcharge reduction would be \$10 209.36. Thus, the demonstration project resulted in an estimated yearly saving of \$14 865.02, and the payback period would be less than two months.

4.4.9 Summary of the Water and Waste Conservation Program at Dvorkin Meat Packers Ltd. The demonstration project at Dvorkin Meat Packers Ltd. involved complexities which make precise evaluation difficult. Throughout the study period the plant was in the process of upgrading its facilities and procedures. These on-going changes interfered with monitoring and with determination of cause-and-effect relationships between a particular modification and resulting water usage and waste loading characteristics. A sharp reduction in plant throughput and mechanical difficulties in

effluent sampling injected further uncertainty as to the exact results of the demonstration project.

Nonetheless, it is apparent that the combination of this project and the plant-initiated modifications were highly successful in reducing water consumption and waste loadings. A conservative estimate of water use savings contributed by the demonstration project alone is 9.4 percent annually, and the daily weight BOD₅ was reduced by greater than 50 percent.

The economic investment to achieve these improvements was only \$2852. Estimated return on the investment is almost \$15 000 annually. Consistent with the Prime Packers study, a major portion of the savings resulted from improved blood collection procedures, which substantially reduced municipal effluent overstrength surcharges.

In the area of water use reductions, flow control devices installed on goosenecks proved to be an extremely economical means of reducing potable water requirements. As at Pinecrest Foods, it was found that these unobtrusive and "tamper-proof" controls lend themselves quite well to slaughterhouse water conservation programs.

Another water use modification worthy of note is the plant-initiated modification involving removal and redirection of nozzles in the automatic carcass wash. This very efficient piece of equipment can also be a highly water-consumptive one. As Dvorkin determined, its water usage may be easily reduced without detriment to product quality.

A key element in the success of the demonstration project was the strong commitment of management at Dvorkin. Study personnel believe that the demonstration project was instrumental in bringing about this commitment, by increasing plant awareness of the economic importance of conservation. Plant management was able to effectively incorporate conservation measures into their general plans for upgrading the plant facility.

5 **IMPLICATIONS OF DEMONSTRATION STUDIES FOR THE CANADIAN MEAT AND POULTRY PROCESSING INDUSTRY**

The demonstration studies confirmed that water use and waste load reductions could be readily accomplished at minimal cost in Canadian meat and poultry processing operations. In all four demonstration plants, reductions in water use resulted from the water and waste management programs. The relative savings in annual usage varied from about 10 percent to over 25 percent. Considerable reductions in process effluent waste loadings were accomplished at both red meat packing plants. There was no significant decrease in the waste load at either of the two poultry processing plants.

The results of the demonstration studies are summarized in Table 57. In all cases, the payback period on the costs of the modifications was less than one year. The savings resulted from a combination of reduced water and sewer costs, as well as substantial reductions in the high-strength effluent surcharges levied against two of the plants. At one plant, a substantial return-on-investment was associated with the sale of blood recovered as a result of the in-plant modifications. A breakdown of the annual savings at each plant is given in Table 58.

The total cost of all modifications in the demonstration plants was approximately \$21 000. The total annual return realized as a result of these modifications was in excess of \$51 000.

5.1 **Applicability of Previous Management Studies to the Canadian Meat and Poultry Processing Industry**

The results of these demonstration studies, in general, were consistent with the results achieved during previous water and waste management studies reported in the literature. Most of these studies were conducted in the United States. The present demonstration studies in Canadian plants revealed that the methods utilized in the United States are directly transferable to the Canadian meat and poultry processing industry with several notable exceptions.

- Coop washing, which is not generally practiced in the United States, was found to be a significant water consuming process in Canadian poultry processing plants. It is also a process which is readily amenable to a water conservation program.
- Due to differences in scalding procedures between the United States and Canada, American experience in reducing the water use associated with defeathering and

TABLE 57 SUMMARY OF DEMONSTRATION STUDY RESULTS

Plant	Reduction in Annual Water Use		Reduction in Waste Load (BOD ₅)		Cost of Modifications (\$)	Annual Savings (\$)
	m ³	Percent	kg/d	Percent		
Pinecrest Foods (Poultry)	97 732	26	N .S.	-	5 948.37	16 027.68
Checkerboard Foods (Poultry)	24 272	12.3	N .S.	-	3 259.98	3 528.50
Prime Packers (Beef, Sow)	20 500*	20.8	342	48.4	9 221.53	17 295.00**
Dvorkin Meat Packers (Beef)	28 390***	9.4	673	55.9	2 852.15	14 865.02

N.S. = Not Significant

* Excludes reduction due to installation of air-cooled refrigeration system.

** Includes revenue realized from sale of recovered blood.

*** Excludes savings achieved by plant-implemented modifications, installed concurrently with demonstration project.

TABLE 58 BREAKDOWN OF ANNUAL SAVINGS RESULTING FROM
DEMONSTRATION STUDIES

Plant	Annual Savings (\$)			
	Water	Sewerage	Surcharge	Total
Pinecrest Foods	8 904.24	7 123.44	0.00	16 027.68
Checkerboard Foods	2 566.18	962.33	0.00	3 528.50
Prime Packers	4 920.00*	-	5 125.00	17 295.00**
Dvorkin Meat Packers	2 586.48	2 069.18	10 209.36	14 865.02***

* Water and sewerage costs combined.

** Includes an estimated \$7 250 realized on the sale of recovered blood.

*** Excludes savings achieved concurrently by plant-implemented modifications. These comprise: \$5 172.96 in water costs, \$4 138.42 in sewerage costs, and \$20 531.28 in overstrength surcharges.

bird washing operations may not be applicable to the sub-scalded poultry commonly produced in Canada.

- High-pressure cleaning and sanitizing equipment, although recommended in the literature, was not readily accepted by plant management involved in these particular studies. All four demonstration plants were equipped with such systems, but they were used to a limited extent for specific tasks. They were considered to consume excessive time and labour for many general cleanup tasks.
- The two poultry plants involved in these demonstration studies were not as amenable to waste load reductions as was suggested by other studies. Despite significant reductions in water use, no reduction in waste load could be documented.
- Although the installation of troughing is widely suggested in the literature to maximize blood recovery, space constraints precluded the use of this approach in most instances.
- The importance of a full-time water management coordinator is often emphasized as imperative to the success of programs similar to these demonstration studies. In many instances, costs associated with a full-time coordinator may negate any savings accomplished as a result of the program. However, it is necessary that someone at the plant be responsible, on a less than full-time basis, for monitoring

water use, implementing control schemes and ensuring that plant management are aware of the situation on a regular basis.

- The site-specific nature of water use patterns at an individual plant will determine the feasibility of any specific water or waste management modification. Such factors as space, plant layout, equipment limitations, costs of water and waste disposal, location of drains and water lines, and plant water pressure will impose constraints on the modifications which may be applied.

At the same time, many important points emphasized in other water and waste management programs were confirmed in these demonstration studies.

- Considerable reductions in water use and/or waste load can be accomplished in red meat and poultry processing operations at minimal expense. Very rapid payback on the cost of the modifications will result.
- As reported in other studies, control of blood losses in both red meat and poultry processing operations is the most important factor in controlling the waste loads.
- Wherever possible, water use should be controlled automatically rather than manually. Minimizing the human involvement in water use will eliminate the need for constant supervision.
- Processes that do not involve direct contact between water and edible product are most amenable to reuse/recycle schemes.

5.2 Water Use Practices and Controls in Meat and Poultry Processing

In the two poultry processing plants, a large fraction of the daily water use was associated with general plant cleanup, chilling of poultry and giblets, coop washing and vacuum pump seal water. The first two processes, cleanup and chilling, are commonly identified as major water use areas in poultry processing; however, the latter two processes are seldom mentioned. The actual quantities of water, on a production basis, associated with each of these unit processes varied considerably between the two plants. Some water uses, such as goosenecks and rotary screen backwash, were identified as major contributors to the total flow at one plant and relatively minor contributors at the other plant.

Similarly, in red meat processing operations several common areas of high water use were identified, including cleanup, viscera table wash, shroud washing and employee handwashing on the kill floor. Most of these high water use areas have been

identified in other investigations; however, some, such as shroud washing, are seldom mentioned in the literature as major contributors to total plant water consumption.

It is evident from the results of these demonstration studies that the areas of emphasis for a water management program in a particular plant will depend on the specific areas in that plant where excessive water use is evident. Plant personnel should have a good knowledge of practices in the plant before instituting modifications to control water use.

Despite the site-specific nature of water and waste management programs, these demonstration studies identified an approach which should be considered in implementing such programs. A stepwise procedure is outlined below, with examples from these demonstration studies of areas where each step was successfully instituted.

- 1) Eliminate completely any water use that is not necessary for cleanliness, heat transfer or material transport. Examples include:
 - increasing dry cleanup as much as possible,
 - eliminating leaks in piping systems by a regular maintenance program,
 - eliminating sidepan wash on eviscerating troughs if unnecessary,
 - eliminating fresh water makeup for feather transport by improving flow patterns in flumes.
- 2) Identify areas where a relatively clean but non-potable water supply could replace fresh water, and identify suitable non-potable water sources which might be reused. In most cases, emphasis should be placed on unit processes not involving direct water-product contact. Examples include:
 - reusing vacuum seal water for coop washing and backwashing rotary screens,
 - reusing carcass wash water for transporting paunch manure,
 - using compressor cooling water for washing inedible tripe.
- 3) Convert continuous water usages to intermittent usages wherever possible. The control system should be automatically activated to eliminate the need for manual control. Examples include:
 - installing timer-operated solenoid valve on shroud wash system,
 - installing solenoid valve on beef blood bucket conveyor shower system,
 - installing solenoid valve on carcass shower to activate system only when product is in a wash position,
 - using suitable hand-, foot- or body-operated valves on handwashers and goosenecks,
 - using automatic shut-off valves on cleanup hoses.

4) Reduce continuous and intermittent flows as much as possible by applying lower volumes of water more efficiently. Examples include:

- using flow-restricting nozzles on cleanup hoses,
- installing flow-control valves on goosenecks, handwashers and other unit processes to limit the flow rate to the minimum required for efficient operation of the process,
- substituting efficient spray nozzles and pressure regulators for domestic showerheads and drilled pipes.

During these demonstration studies, a number of modifications proved to be relatively unsuccessful. However, it is possible that these same modifications could be substantially more successful in another plant.

It was demonstrated at the College Hill poultry plant in the U.S. that water use in poultry processing can be reduced to less than 10 L/bird (8). Maintaining water consumption at such low levels requires a total commitment from management, labour and inspection personnel. Unless there are severe limitations on the quantity of water available or on the facilities to handle the waste load, the economic feasibility of optimizing plant operation to this extent is questionable, given existing water and waste disposal costs.

These demonstration studies have shown that water consumption in the range of 20 to 30 L/bird can be readily achieved in most instances. Further reductions in water use may be difficult to attain without substantial capital investment and sophisticated recycle/reuse schemes. The feasibility of such approaches will depend on the site-specific costs of water and waste disposal compared to the operating, maintenance and capital costs of renovating for water reuse. Maintaining water usage at less than 20 L/bird is considerably more difficult than reducing water use to the level of 20 to 30 L/bird. Optimizing water use to this degree may not be warranted except under specific circumstances.

Innovative processes such as dry chilling, steam scalding and microwave scalding have not as yet been developed to the point where they are competitive with existing technology in terms of economics and product quality. Dry offal transport systems may not reduce water use significantly unless a considerable consumption related to sidepans and goosenecks can be eliminated. Similarly, dry feather transport systems will not affect water use significantly, as the feather flume system should operate without fresh water makeup if properly designed.

In the red meat processing industry, it is more difficult to place a limit on the achievable water usage due to the wider variety of processes and products involved. In these demonstration studies, a production-based usage of 3.75 L/kg dressed weight was achieved. This is a very low water usage by industry standards and, in this case, further reductions would be difficult and expensive to achieve. Unlike the poultry processing industry, red meat processing involves considerable variation in equipment and unit processes. Therefore, the lower limit on water usage is even more site-specific.

5.3 Waste Management in Meat and Poultry Processing

Reduced process effluent waste loads from meat and poultry processing operations are more difficult to achieve consistently than reduced water use. There are fewer options available and it is difficult to eliminate the human element. Constant supervision is necessary to ensure that dry cleanup practices are maintained and that plant personnel are aware of the various major inputs to the plant waste load.

The demonstration studies confirmed the importance of adequate blood collection in controlling waste loadings. A large fraction of the annual savings realized at both red meat plants was associated with reduced surcharges resulting from improved blood collection. In addition, Prime Packers realized a substantial return on the sale of recovered blood. At two of the demonstration plants, there was considerable cost involved in the disposal of recovered blood as no markets were available for this material. The development of markets for blood by-products would add extra incentive to recover blood. Where no municipal sewer surcharge is imposed and the processor must pay to dispose of blood, there is no incentive to recover this material.

Equipment such as dry offal transport and dry feather transport systems can have economic advantages depending on the cost of waste disposal. In general, the reduction of waste loading involves more substantial capital investment than the reduction of water use. In addition, the economics of waste load reduction are complicated by such factors as sewer surcharge rates, and operation and capital cost of industrial waste treatment facilities.

5.4 Economics of Water and Waste Management Programs

Most water and waste management programs have emphasized the economic incentives associated with control of water use and reduction of waste loads from meat and poultry processing operations. These demonstration studies confirmed that annual savings can be realized; however, the magnitude of the savings depend on the degree of

reduction that can be accomplished and the local costs associated with purchasing water and disposing of process effluent. A review of the tabulated water and sewer costs and surcharge levies across Canada (Appendix C) indicates that in some areas there is little economic incentive to control water use and waste loads. Furthermore, the sewer surcharge formulae in some areas provide no incentive for water and waste management programs.

Where total water and sewage costs are only $\$0.11/\text{m}^3$, substantial savings in water use would be necessary to justify the expense of the management program. Only processors using significantly more water than the industry average could justify extensive conservation programs on an economic basis. Conversely, in areas where water and sewer costs approach $\$0.33/\text{m}^3$, even plants that have demonstrated good water use practices could justify further reductions.

The implications of overstrength sewer surcharges are more complex. In most cases, surcharges are assessed only if the waste strength is in excess of a predetermined bylaw limit. A plant not previously surcharged could have a surcharge imposed as a result of a water conservation program if water use is reduced such that the waste strength increased beyond the bylaw limits. This surcharge could be imposed despite an overall reduction in the total plant waste load if the reduction in water use was significantly greater than the reduction in waste loading. Although substantial savings can be realized at a plant that is presently paying a surcharge by reducing waste loadings, it is extremely important that plant management understand the method of calculation related to overstrength sewer surcharges.

A final important economic implication of water and waste management programs relates to plants that require their own treatment or pre-treatment facilities. At an existing plant with a well-operated treatment facility, relatively little savings will be realized in operating and maintenance cost as a result of water and waste management programs unless a considerable reduction in waste loading can be translated to reduced sludge disposal, aeration or chemical requirements. However, substantial savings could be realized in an overloaded pretreatment facility if plant efficiency can be improved to such a degree that sewer surcharge could be reduced or eliminated as a result of a reduction in hydraulic or waste loading. Furthermore, any plant considering a new treatment facility or expansion of an existing facility to handle an increase in production rates could realize a large savings in capital cost from in-plant control of water use and

waste loadings since most treatment processes are designed on the basis of hydraulic or organic loading.

Again, the economic feasibility of a water and waste management program is very site-specific. It is most important that plant management realize the present costs of water and waste disposal and are aware of potential inflation of these costs in the future.

5.5 Relevance to the Canadian Meat and Poultry Industry

The savings realized as a result of these demonstration studies cannot be accurately extrapolated to define the overall impact on the Canadian meat and poultry processing industry. Most plants can accomplish some savings at minimal cost. However, in some areas, no economic incentive exists for water and waste management programs. Undoubtedly, water and sewer costs will continue to increase. More municipalities will find it necessary to introduce a sewer surcharge system to recover the cost of industrial waste treatment. As these operating expenses increase, more plants will find investigation of in-plant methods of controlling water use and waste loadings economical.

A considerable amount of information is available to allow plant management to evaluate the economics of in-plant water and waste control programs and institute steps that are feasible within the constraints at a particular plant. It is important that the approval of Agriculture Canada be secured for any in-plant modification that might affect product quality.

5.6 Recommendations

As a result of this investigation, a number of possible reuse/recycle schemes were identified that would require detailed evaluation to ensure acceptance by Agriculture Canada. These include such water-conserving practices as:

- reuse of chiller overflow for gizzard splitting and fluming,
- reuse of screened prechiller overflow as makeup for scalders, and
- use of recycled water in the first stages of swine dehairing equipment.

The feasibility of such water reuse schemes should be investigated.

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APPENDIX A LITERATURE REVIEW

A.1 Water and Waste Management in the Poultry Processing Industry

The poultry processing industry slaughters, eviscerates, cuts up and packages chicken, cornish hens, fowl, turkey, and waterfowl. Some establishments also cook, can, or conduct other further processing of poultry. A plant may process one or several types of birds. Some plants render their own byproducts, while others send them to an independent renderer.

This section of the literature review deals with water and waste management practices applicable to poultry slaughtering, eviscerating, and packing operations. Rendering operations are included in Section A.3.

Chickens are the main poultry processed in Canada and the U.S. The category "chicken" includes broilers (up to 46 days old) and slightly older, larger birds, sometimes called roasters. Consequently, most of the literature available addresses water and waste management in chicken plants. There are relatively few studies concerning fowl, turkey, or waterfowl processing.

An attempt has been made to consult primary sources for data. Secondary sources were sometimes found to misquote or misinterpret data from primary sources. Secondary sources were occasionally consulted when primary data were unobtainable. Citations refer to primary sources, when available; secondary sources reiterating the same information are not cited.

The reader should be aware of the limitations of the data found in the literature review. It is often difficult to generalize from one particular study to other plants or to the industry in general, and comparisons among studies are not always possible. The problems include:

- Plants that have been studied vary significantly, and the details of plant operations are not always explicit. Some sources of variation include production level, production mix (types of birds), processes conducted (e.g., further processing), and equipment types. The mere fact of physical size or floor space can make a tremendous difference in cleanup water use, yet size is not mentioned in the studies reviewed here.
- Sampling points that appear to be the same in two studies may, in fact, be quite different. An example is the feather flowaway, which can collect process wastewater from several different unit processes. One plant may use the flowaway to collect scalding, coop wash, and defeathering water while another collects defeathering and whole bird wash water in its flowaway. Comparisons of pollutant

parameters and flow rates in the two flowaways would carry little meaningful information. Another example is overall waste loads. Wastewater may be sampled before or after treatment, or between treatment stages. Studies often do not make explicit the locations of their sampling points.

- Studies have collected and analyzed data in various ways that do not allow easy comparisons. For instance, some measure overall sewage strength with BOD₅, while others use COD. Sometimes pollutant parameters are described as concentrations, sometimes as gross weight, and other times as weight per unit product. When the data is presented in one format, an attempt was made here to convert it into other formats, to facilitate comparisons among studies. At times, assumptions had to be made to convert the data (e.g., assume an average live weight of 1.59 kg per bird when only numbers of birds were supplied by the source). At other times there was simply not enough information provided to permit conversions.
- Studies that relied on questionnaire responses may have a large data base, but one of questionable accuracy. Also, the response may comprise a biased sample. On the other hand, in-plant studies may have too small a data base to allow generalization to other plants.

Figure A.1 schematically illustrates the flow of operations at a poultry processing plant. The sequence and particular conduct of operations will vary among individual plants.

A.1.1 Water Use in the Poultry Processing Industry. Most operations in poultry processing involve water, for cleansing edible product, and employee's hands, implements, and the processing machinery. Water is also commonly used for transporting edible and inedible product, for scalding (to facilitate feather removal), and for chilling eviscerated poultry. Although it is generally agreed that the industry is water intensive, published figures show wide variation. Tables A.1 and A.2 summarize the figures reported in the literature.

As shown in Table A.1, water use in poultry processing in the 1950's and 1960's generally was reported to be in the range of 25 - 30 L/bird. This period was transitional for the poultry processing industry. Technology was advancing rapidly and sanitation was improving substantially. "New York dressed" poultry (uneviscerated) was disappearing (2). These three trends contributed to increased water consumption. Flowaway systems for offal and feathers were being installed throughout the industry. Although flowaways saved labour, they were responsible for a large share of the increase in water use. The

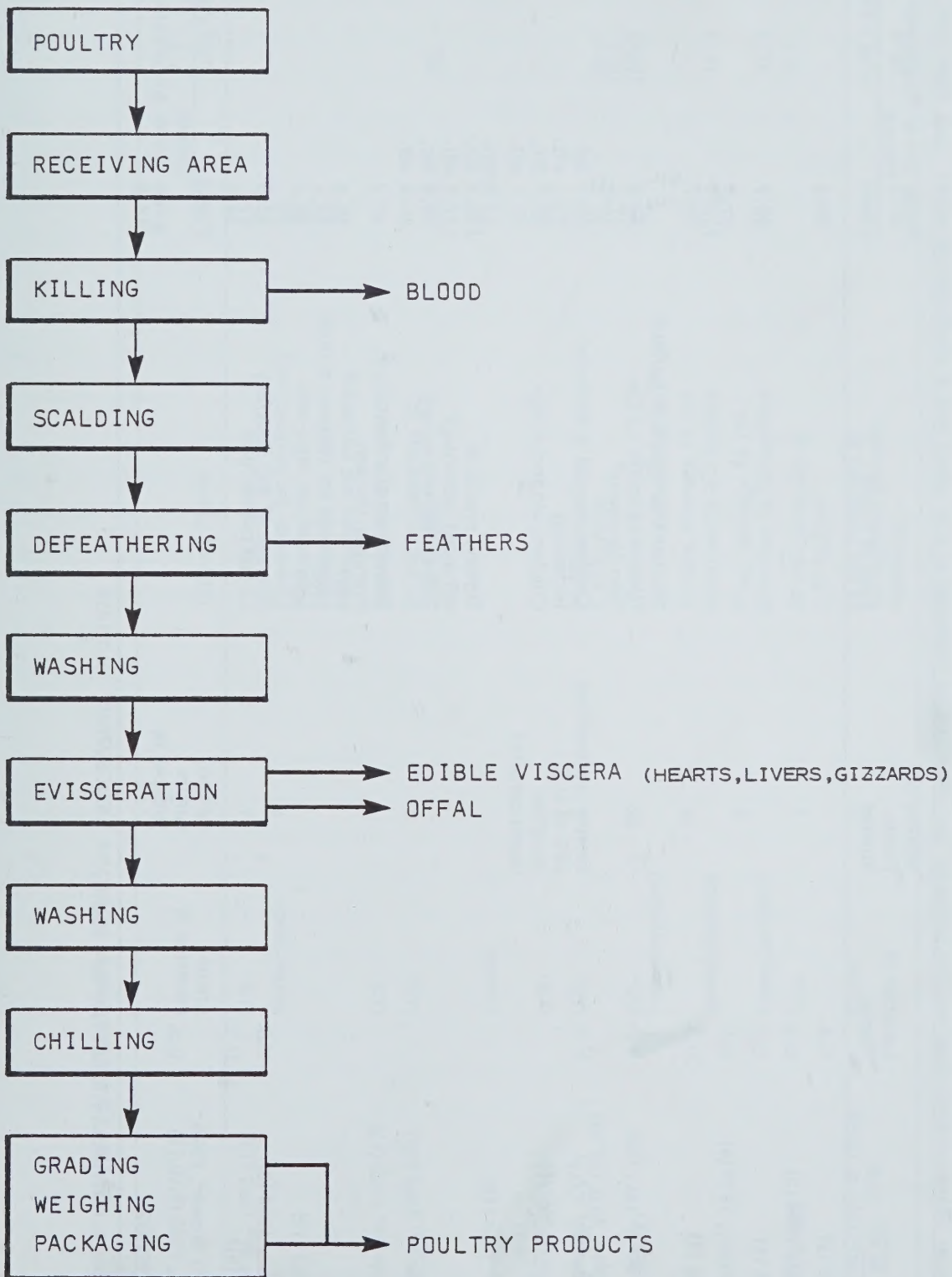


FIGURE A.1 PROCESS FLOW OF A POULTRY PACKING PLANT

TABLE A.1 REPORTED WATER USE IN POULTRY PROCESSING, 1950-1969

Source	Location of Plants	Number of Plants Studied	Type of Plants	Water Use or Wastewater Volume	
				L/bird	L/kg LWK
Porges, 1950 (1)	U.S.			26.6	
Kahle & Gray, 1956 (2)	U.S.				1.7
Bolton, 1958 (3)	U.S.			25.1	
Ingols & Gaffney, 1959 (4)	U.S.			27.2	
Whiten, 1961 (5)	U.S.			24.7	
Porges & Struzeski, 1962 (6)	U.S.	13	Chicken (reported 1.58 kg/bird) "flowaway" "non-flowaway"	30.3 17.0	19.2 10.9
U.S. FWPCA, 1967 (7)	U.S.	Sample representing 28% of U.S. slaughter (questionnaire)	Chicken, typical & advanced technology Chicken, old technology	34.1 inf. 33.1 eff. 22.7 inf. 22.1 eff.	
			Turkey, typical & advanced technology Turkey, old technology	136.4 inf. 132.4 eff. 90.8 inf. 88.4 eff.	
			Projections of industry averages, chicken	28.5 27.4 28.4	
Vasuki & Sabis, 1968 (8)	U.S.	6	Average 67 883 birds/day	32.5	
Camp, 1969 (9)*	U.S.	1		28.8	
Camp, 1969*; Brewer, 1969; Hamm, 1970 (9,10,11)	U.S.				6.9
Nemerow, 1969 (12)				18.9	

* Citations in references (13) and (14) vary slightly.

TABLE A.2 REPORTED WATER USE IN POULTRY PROCESSING, 1970-1978

Source	Location of Plants	Number of Plants Studied	Type of Plants	Water Use or Wastewater	
				L/bird	L/kg LWK
Woodard, et al., 1972 (15)	U.S.	1	72 000 broilers/day	45	
Erdsieck & Gerrits, 1973 (16)	Netherlands	7	Flowaway for feathers only	26	
			Flowaway for offal only	36	
			Flowaways for feathers & offal	35	
			Flowaways and rendering	44	
Kerns & Holemo, 1973 (17)	U.S.		Includes further processing	40.5	
Carawan, et al., 1974 (14)	U.S.	1	69 200 broilers/day @ 1.66 kg/bird	46.5	28
Stanley Associates, 1974 (18)	Canada			13.6-68*	
Whitehead, et al., 1975 & 1976 (19,20,21)	U.S.	1		34.1	
Frost & Woodard, 1975; Woodard, 1976 (22,23)	U.S.	2	90 000 birds/day @ 1.59 kg/bird	37.9	23.8
U.S. EPA, April, 1975 (24)	U.S. (questionnaire)	88	Chicken, average 73 000 birds/day @ 1.74 kg/bird	34.4	19.8
	(questionnaire)	34	Turkey, average 12 100 birds/day @ 8.3 kg/bird	118.2	14.2
	(questionnaire)	8	Fowl, average 34 100 birds/day @ 2.3 kg/bird	48.9	21.3
McGrail, 1976 (25)	U.S.	1	50 000 birds/day @ 1.59 kg/bird	26.5	
Hamza, et al., 1977 & 1978; Witherow, et al., 1978 (26,27,28)	Egypt	1	13 083 birds/day @ 1.1 kg/bird; includes rendering	31.5	28.6

* Personal communication with authors indicated the higher figure published in this report was a typographical error. This table uses the corrected figure.

differences in water use between modern flowaway plants and the older style non-flowaway plants can be seen in the figures reported by Porges and Struzeski in 1962 (6) and by the U.S. FWPCA in 1967 (7), shown in Table A.1. (In the FWPCA data, non-flowaway plants were designated as utilizing "old" technology.)

By the early 1970's, most plants were using flowaway systems, reflected in the water use figures shown in Table A.2. Water was a relatively inexpensive, virtually limitless commodity in most places, and water use in excess of 40 L per bird was often reported.

The vast majority of studies of water use in poultry processing have been conducted in the U.S. There is little evidence that overall water use in Canadian plants differs substantially from that of their American counterparts. Processing operations and inspection regulations regarding water use are fairly similar in the two countries.

There are, however, two factors which might cause more water consumption by Canadian plants. For one, Canadian plants are required to wash coops, whereas American plants are not. Canadian plants, on the average, are also much smaller than American plants. In a 1974 survey of the Canadian industry (18), 49% of all plants were classified as "large", slaughtering an average live weight over 33 000 kg/d. The remaining plants were much smaller. A U.S. survey published in 1975 (24) showed an overall average of 73 000 birds per day with an average live weight of 1.74 kg/bird. The average U.S. plant was, therefore, about four times larger than a large Canadian plant. This difference means that Canadian plants are not able to utilize certain economies of scale available to American poultry processors. Because their production is so much higher, American plants may use less water per unit product than Canadian processors. However, the evidence for this speculation is contradictory. In its 1975 development document (24), the U.S. Environmental Protection Agency (EPA) noted that its survey of processors indicated no relationship between effluent volume and plant size. If that is the case, then large plants would tend to use less water per unit product than small plants. On the other hand, unpublished data from an Environment Canada inventory in 1974 (18) showed large plants using slightly more water per unit product than small plants.

The only published Canadian data found (18) suggests the average water use per bird ranges from 13.6 L to 68 L*. Unpublished questionnaire data from the same

* Personal communication with the authors of that document indicated that a typographical error caused the report to read "three to five gallons" instead of "three to fifteen gallons."

study indicates an average of about 33.3 L/bird for small plants (average 700 000 kg/year) and 36.3 L/bird for large plants (average 8.25 million kg/year), assuming an average live weight of 1.59 kg/bird. However, these figures should be taken as "order of magnitude" estimates only.

The questionnaire response represented 59 percent of the total Canadian slaughter, but was regionally biased. Of the 68 plants responding, only 46 supplied water use data. More significantly, it is questionable whether most of the plants responding to the survey had accurate knowledge of their water consumption. When a plant manager or superintendent is asked to supply water use figures, he often has no precise data readily available. It is likely that in 1972, water was so inexpensive that poultry plants paid little attention to their total consumption.

Each plant was asked to record the total volume of water used in 1972. This figure was adjusted for total slaughter to yield a volume per 1000 lbs LWK, which could then be divided by average live weight to estimate volume per bird. The immense variation in response can be seen in the examples of two plants: one large plant in Ontario reported 13.1 Igal/1000 lbs LWK (approximately 0.25 L/bird), while a small plant in an eastern province reporting 6 438 Igal/1000 lbs LWK (or about 102.25 L/bird). These variations lend credence to the assertion that plants responding to a questionnaire may not provide accurate data on water use.

A lack of information about water use in plants processing types of poultry other than chicken exists. The evidence available (24) indicates turkey processors use three to four times as much water per bird as do chicken processors, but turkey processors use less water per kilogram live weight killed, as the average turkey is almost five times as heavy as an average chicken. Fowl processing on the other hand, appears to use more water per bird than chicken processing in approximate proportion to the larger size of the fowl.

The studies summarized in Tables A.1 and A.2 display a range of figures on water use in the poultry processing industry. In part, they reflect the large variation typically found from plant to plant. Plant size, both physical facility and total production, process mix, plant equipment, the types of birds processed, water availability and cost all contribute to substantial differences in water used from plant to plant.

None of the studies reviewed used random sampling techniques. Thus statistical confidence limits cannot be placed on any of the estimates of average water consumption.

A dilemma faces the researcher interested in drawing an accurate picture of average industry-wide water use. On one hand, he can choose to actually measure water use at a sample of plants. However, the costs of such an undertaking would be prohibitive if the sample size were large enough to be meaningful. On the other hand, he can choose to survey by means of a questionnaire. The costs of data collection with a questionnaire are much more affordable, but the results are likely to be less accurate than those derived from actual observation for the reasons discussed above.

In the final analysis, a precise estimate of average water consumption of poultry plants would be of little value, except to satisfy scientific curiosity. The studies that have been done, while not scientifically impeccable, provide what industry and interested government agencies need: a general indication of the typical upper and lower limits of poultry plant water use, and "ball park" estimates of average consumption. A poultry plant wishing to evaluate its own water use should not use the question, "Is this plant better or worse than the industry average?" to judge its situation. A more realistic criterion can be provided by answering the question, "What are the ways this plant can economically reduce its water use and thereby reduce its costs per unit product?"

A.1.2 Waste Loads in the Poultry Processing Industry. Waste loads in poultry processing are caused by dirt, blood, feathers, faecal matter, grit, body tissue, and fat mixing with wastewater flows. The most common parameters for measuring poultry plant waste loads are five-day biochemical oxygen demand (BOD_5), suspended solids, and fat, or oil and grease. The levels of these parameters reported in the literature are summarized in Tables A.3, A.4 and A.5.

The information provided in these tables exhibits wide variation for a number of reasons. They include:

- differences in production mix - both types of bird and types of in-plant operations. Studies do not always make these variables explicit.
- differences in sampling point locations. Again, it is not often clear whether a sample has been taken, for instance, before or after an air flotation cell.
- differences in poultry flocks. Some birds may generate greater wasteloads per unit weight than others.
- differences in volume of water use. When a study supplies only concentrations and water volume is not given, it is impossible to calculate actual waste loads.
- differences in degree and effectiveness of in-process prevention of wastes mixing with spent process water. Similarly, differences in degree and effectiveness of treatment, in cases where wastewater has been sampled after treatment.

TABLE A.3 REPORTED BOD₅ IN POULTRY PROCESSING

Source	Location of Plants	Number of Plants Studied	Type of Plants	BOD ₅		
				mg/L	kg/day	kg/1000 birds kg/1000 kg LWK
Porges, 1950 (1)	U.S.	13		428		11.4
Bolton, 1958 (3)				446		11.2
Ingols & Gaffney, 1959 (4)	U.S.			456		12.4
Whiten, 1961 (5)	U.S.			498		12.3
Porges & Struzeski, 1962 (6)	U.S.		Flowaway, blood recovered			11.3
			Flowaway, blood sewered			18.6
			Non-flowaway, blood recovered			10.4
			Non-flowaway, blood sewered			15.9
U.S. FWPCA 1967 (7)*	U.S.		"Advanced" technology Assume 1.59 kg/bird	428	1 772	11.8
						7.4
Camp & Willoughby, 1968 (7)	U.S.	1		473		
Vasuki & Sabis, 1968 (8)	U.S.	6	5 000 to 10 000 birds/hour Assume 1.59 kg/bird	414	914	13.5
						8.5
Camp, 1969 (9)	U.S.	1		615		
Woodard, <u>et al.</u> , 1972 (15)	U.S.	1	72 000 broilers/d Assume 1.59 kg/bird	397	1 293	18.0
						11.3
Erdtsieck & Gerrits, 1973 (16)	Netherlands	7	Flowaway for feathers only Assume 1.59 kg/bird			4.9
			Flowaway for offal only Assume 1.59 kg/bird			6.9
			Flowaways for feathers & offal Assume 1.59 kg/bird			10.2
			Flowaways and rendering			18.3
Carawan <u>et al.</u> , 1974 (14)	U.S.	1	Assume 1.59 kg/bird 69 200 broilers/day before changes	560	1 801	26
						11.5
						15.7

TABLE A.3 REPORTED BOD₅ IN POULTRY PROCESSING (Cont'd)

Source	Location of Plants	Number of Plants Studied	Type of Plants	BOD ₅		
				mg/L	kg/day	kg/1000 birds
U.S. EPA, 1975 (24)	U.S.		After changes, 73 800 broilers/day	390	850	11.5
			After changes, effluent after settling and air flotation	282	615	8.3
			60 Chicken processors @ 73 000 birds/day	500	1 256	17.2
			15 Turkey processors @ 12 100 birds/day	347	496	41
			4 Fowl processors @ 34 100 birds/day	715	1 192	35.0
Frost & Woodward, 1975; and Woodward, 1976 (22,23)	U.S.	2	90 000 broilers/day	534	1 815	20.2
			9 600 birds/hour	1 116		12.7
Whitehead, et al., 1976 (21)	U.S.	1				
McGrail, 1976 (25)	U.S.	1	50 000 birds/day	539	612	12.2
Chen, et al., 1976 (30)	U.S.	19		731		
Lounsbury et al., 1977 (31)	U.S.	1	30 000 birds/day	675		
Hamza, et al., 1977 & 78; Witherow, et al., 1978 (26,27,28)	Egypt	1	13 083 birds/day includes rendering	1 306	426.8	32.6
						29.6

* A discrepancy among the figures reported in this study makes the data uncertain. The following data are reported in one table:

- Old Technology: 655 lbs BOD₅ and 25 000 birds processed per day.
- Typical Technology: 3 966 lbs BOD₅ and 125 000 birds per day.
- Advanced Technology: 3 907 lbs BOD₅ and 150 000 birds per day.

Dividing the weight of BOD₅ by the number of birds per day yields:

- Old Technology: 26.2 lbs/1000 birds
- Typical Technology: 31.7 lbs/1000 birds
- Advanced Technology: 26.0 lbs/1000 birds

However, another table reports:

- Old Technology: 31.7 lbs/1000 birds
- Typical Technology: 26.2 lbs/1000 birds
- Advanced Technology: 26.0 lbs/1000 birds

The source of the discrepancy is unclear. If the first table is correct, then the figures for Old and Typical Technologies are simply transposed in the second table. However, other evidence makes it implausible that Old Technology, in which all blood was sewered, would cause a lower BOD₅ per bird than Typical Technology, in which blood was recovered. Because of this uncertainty, only data for advanced technology are included here.

TABLE A.4 REPORTED SUSPENDED SOLIDS IN POULTRY PROCESSING

Source	Location of Plants	Number of Plants Studied	Type of Plants	Suspended Solids		
				mg/L	kg/day	kg/1000 kg LWK
Porges & Struzeski, 1962 (6)	U.S.	10	Flowaway, blood recovered		5.9	3.7
		5	Flowaway, blood sewered		10.4	6.6
		1	Non-flowaway, blood recovered		5.4	3.4
		2	Non-flowaway, blood sewered		9.5	6.0
Vasuki & Sabis, 1968 (8)	U.S.	5	Average 66 100 birds/day assume 1.59 kg/bird	294	648	6.2
Woodard, <u>et al.</u> , 1972 (15)	U.S.	1	Average 72 000 broilers/day assume 1.59 kg/bird	336	1 093	9.6
Carawan, <u>et al.</u> , 1974 (14)	U.S.	1	Gold Kist plant before changes: average 69 200 broilers/day	375	1 206	10.5
			After changes, 73 800 broilers/day, after settling and air flotation	214	466	3.7
U.S. EPA, April, 1975 (24)	U.S.	53	Chicken processors, average 73 000 birds/day	350	878	6.91
		13	Turkey processors, average 12 100 birds/day	223	318	3.17
		4	Fowl processors, average 34 100 birds/day	475	791	10.09
Frost & Woodard, 1975; Woodard, 1976 (22,23)	U.S.	2	Average 90 000 birds/day	411	1 398	9.8
Whitehead, <u>et al.</u> , 1976 (21)	U.S.	1	Average 9 600 birds/hour	368		
Chen, <u>et al.</u> , 1976 (30)	U.S.	19		491		
McGrail, 1976 (25)	U.S.	1	Average 50 000 birds/day	833	946	11.9
Lounsbury <u>et al.</u> , 1977 (31)	U.S.	1	Average 30 000 birds/day	380		

TABLE A.5 REPORTED OIL AND GREASE IN POULTRY PROCESSING

Source	Location of Plants	Number of Plants Studied	Type of Plants	Oil and Grease			
				mg/L	kg/day	kg/1000 birds	kg/1000 kg LWK
Woodard, et al., 1972 (15)	U.S.	1	Average 72 000 birds/day @ 1.59 kg/bird	229	744	10.3	6.5
Carawan, et al., 1974 (14)	U.S.	1	Gold Kist plant before changes-average 69 200 broilers/day	150	482	7.0	4.2
			After changes, average 73 800 broilers/day - raw wastewater	141	314	4.2	2.5
			After changes, wastewater after settling and AFC treatment	64	139	1.9	1.1
			Chicken processors, average 73 000 birds/day	213	535	7.3	4.2
U.S. EPA, April 1975 (24)	U.S.	39	Turkey processors, average 12 100 birds/day	62	89	7.4	0.89
		3	Fowl processors, average 34 100 birds/day	109	182	5.3	2.3
		2	Average 90 000 birds/day	338	1 151	12.8	8.04
Frost & Woodard, 1975; Woodard, 1976 (22,23)	U.S.	1	Average 9 600 birds/day	266	453	9.1	5.7
Whitehead, et al., 1976 (21)	U.S.	1	Average 50 000 birds/day	399			
McGrail, 1976 (25)	U.S.	19		158			
Chen, et al., 1976 (30)	U.S.	1	Average 30 000 birds/day	136			
Lounsbury & Miller, 1977 (31)	U.S.	1					
Hamza, et al., 1977 & 78, Witherow et al., 1978 (26,27,28)	Egypt	1	Average 13 083 birds/day	102	42	3.2	2.9

- differences in sampling times. Some studies rely on single grab samples, others on composite samples taken during production, still others on composite 24-hour samples. The number of samples taken, and when they were taken is not always explicit.

The ideal data set would include:

- the number of plants sampled,
- the location of the sampling point with respect to treatment,
- the number of samples taken, and the times of sampling with respect to production and cleanup activities,
- the total volume of water used,
- major pertinent process information, such as whether or not blood is collected, and any further processing or rendering.

Such complete information is rarely available. In Tables A.3, A.4 and A.5, an attempt was made to include some pertinent sampling and production details and to standardize the data to facilitate interpretation. When the necessary information for calculations was provided, estimates were made to convert the data into comparable formats. For instance, if wastewater concentrations, flow rates, and number of birds were supplied in a study, it was possible to calculate the weight of pollutants, and the weight of pollutants per unit product. If the average live weight per bird was not supplied, it was assumed to be 1.59 kg.

The range of reported $BOD_5/1000$ kg LWK is 3.0 kg to 29.6 kg. On a per 1000 birds basis, the BOD_5 ranges from 4.9 kg to 32.6 kg. The trend over time seems to be toward greater diversity among plants. It is open to speculation whether this is evidence of actual divergence, or simply a function of the variations in sampling enumerated above. Reported suspended solids and oil and grease levels also display wide variation.

As with water use, a poultry processor's waste load can only be evaluated in terms of the economically achievable. If a plant discharges a heavy waste load to a municipal system and that municipality does not provide economic incentive for waste load reduction, the processor must conclude that its effluent is acceptable. At the other extreme, if a plant discharges directly to receiving waters, and governmental regulations are stringent, only the most purified effluent may be acceptable.

Poultry processing potentially places a heavy pollutant burden on treatment systems and receiving waters. However, it is generally agreed that much of the potential waste load can be prevented from ever entering plant effluent, and that the remaining unavoidable waste load can be greatly reduced through efficient waste treatment.

In spite of the variability in reported data there are a few generalizations that can be made about wasteloads in poultry processing.

The majority of pollutants are discharged during the production shift. A 1958 study reported that in plants with flowaway systems, 75 percent of the BOD₅ and suspended solids were discharged during production (3). The figures reported by the U.S. FWPCA in 1962 indicated that in plants with advanced technology, 85% of BOD₅ resulted from the production processes. Similar figures were reported in later studies (15,18,22).

If a plant allows blood to be sewerred, it causes a major BOD₅ load which is easily preventable. Poultry blood has been measured to exert a BOD₅ of 92 000 to 100 000 mg/L (6,8). Because it dissolves so rapidly, the BOD₅ caused by blood is imparted to a waste stream almost instantaneously. It is expensive to remove by treatment. A plant that is attempting to reduce its BOD₅ waste load should look first at instituting blood collection. If it already collects blood, it should examine the system carefully, to make sure there is no leakage into waste streams.

Evisceration is a major source of waste loading. Although there is some contradictory evidence, several studies have found offal flowaway the largest source of production shift waste loads (15,21,23). Technology to greatly reduce the wastes generated in the evisceration is readily available. Dry offal conveyance systems keep most of the evisceration wastes out of effluent streams. However, converting to dry offal transport from a flowaway system requires a major capital investment, and may not always be economical. Less radical solutions to reduce the wastes from eviscerating include reverting to the "old fashioned" method of disposing of inedible poultry parts in barrels or bins. However, the labour involved is likely to make this solution uneconomical. A more economical improvement would be to install more effective screening for recovery.

Dry cleanup procedures are a relatively simple and inexpensive way to reduce overall waste loads. One of the most straightforward solutions to a high waste load problem is to prevent the polluting wastes from ever reaching an effluent stream. Dry cleanup procedures require no sophisticated technology and little additional labour and equipment. A cleanup crew armed with appropriate squeegees, brooms, shovels, and

containers can collect wastes "dry" before washing down plant floors and equipment, thereby reducing the burden on treatment systems.

Reductions in water consumption may also reduce waste loads. Some water use reductions, such as dry offal conveyance and dry cleanup are ways to reduce plant wastes. Less water may also mean less dissolving of solids and thus an effluent more readily treatable by physical means. In addition, a reduced hydraulic loading may allow treatment systems to operate more efficiently.

The sooner solids are removed from waste streams, the lower will be the waste load. Large bits of tissue, feathers, and other solids will impart more BOD₅, oil and grease and small solids as long as they are in contact with the waste stream. Screening them out as soon as possible will have a favourable effect on plant effluent. Pumping has been reported to break up solids, and should be avoided before screening (32).

Although BOD₅, suspended solids, and oil and grease are the major pollutants reported for poultry processing wastes, nitrogen has also become a parameter of concern for measuring the strength of poultry processing effluent. Organic nitrogen may decompose into ammonia, and ammonia and organic nitrogen can oxidize to form nitrates and nitrites. Discharge of these chemicals may have hazardous effects on desirable aquatic life, and on human life. Ammonia can accelerate lake eutrophication.

Proteinaceous materials in poultry plant wastewaters contribute to high levels of nitrogen compounds. Feathers, blood, and animal tissues are the major contributors. One measure of the proteinaceous material is total Kjeldahl nitrogen (TKN).

Typical TKN levels in raw waste water in poultry processing plants range from 50 to 100 mg/L (24). In the U.S., limitations are being placed on TKN discharge to receiving waters, the limits varying with the particular receiving body. Some municipalities are proposing or initiating overstrength surcharges for TKN (33). Therefore, poultry processors are investigating ways to reduce TKN levels in plant effluents.

Minimizing contact between waste water streams and blood, and waste water streams and feathers can reduce TKN. For this reason, some poultry processors in the U.S. are investigating alternatives to feather flowaway systems.

A.1.3 Receiving Areas. In the U.S., only cleanup operations typically require water in the receiving area. In Canada, coop washing is mandatory under Agriculture Canada inspection regulations. Part VIII, Section 127 (6) of the Meat Inspection Act states, "Facilities shall be provided for the cleansing and disinfecting of poultry crates" (34).

Some U.S. plants do practice coop washing, although it is not required under federal inspection regulations. A coop cleaner was installed at Gold Kist (14) where none had been used previously. This was done in response to complaints from nearby residents because feathers from trucks carrying unwashed empty coops littered yards along the route. However, the arrangement described in the final report on the Gold Kist plant appears to provide too superficial a cleansing to be acceptable to Agriculture Canada. Individual coops were sent through a wind tunnel, to remove heavy solids and airborne feathers. A water flow of 19 L/min was used to dampen feathers, to aid in their eventual transport to the feather flowaway trough.

A commercial poultry trucking operation reported a water reuse system for coop cleaning. The firm's Norwesco coop washer cleans individual polystyrene coops, using 750-1150 L of hot water per minute. To conserve water, a vibrating screen separator filters the water, which is then reused. For each batch of 500 coops, about 1900 L of potable water is used (35).

No other literature was found on coop cleaning. The water consumption of two different coop cleaning methods was measured in this study (Sections 4.1 and 4.2). At Checkerboard Foods Ltd., where coops were unloaded from trucks and conveyed through a washing system, the average daily water use was 32 600 L. At Pinecrest Foods, the built-in coops were washed with a spray system which used an average of 170 000 L on days when weather permitted. In both cases, water consumption was reduced by about 50 percent. These figures should not be construed as representative of the industry.

Although no literature was found on coop wash water conservation, some frequently mentioned general principles can be applied:

- Use high pressure, low volume sprays with appropriate nozzles.
- If individual coops are washed automatically, a timer may help prevent needless loss of water.
- If relatively high quality recycled water is available, it may do an adequate job of cleaning coops. Vacuum pump seal water or condensor cooling water are possible sources.
- Use only the minimum time necessary for a thorough cleaning.

Receiving area cleanup is a water use common to all North American plants, and the literature mentioning it is unanimous in recommending a thorough dry cleanup before washdown.

No meaningful figures were available for average water use in receiving area cleanup. The water consumed varies with the size of the area to be cleaned and individual employees' habits and routines. However, if a plant does not use an initial dry cleanup in the receiving area, it is using too much water. Using hoses to scrape and sweep solids from the receiving area floor is an inefficient use of water. Final washdown should be accomplished with a minimum of water, using high pressure/low volume hoses with proper nozzles. Automatic shutoff or valves that can be closed at the nozzle end of hoses also help prevent water waste via hoses left running when not in use. Good cleanup habits by conscientious employees are the most important factors in maintaining low water consumption in the receiving area.

A few Canadian poultry slaughterhouses wash the receiving area with water recycled from other areas of the plant, such as the evisceration trough or the chiller (18). Plants currently washing with potable water would reduce their consumption by instituting recycling, but this is contingent on the availability of an adequate suitable supply. Also, the costs would have to justify the savings. No estimates of cost/benefit ratios were found in the literature.

Dry cleanup in the receiving area can reduce waste loads at least two ways. First, much of the weight of manure and feathers entering the plant are kept out of the sewer entirely. Second, the hydraulic loading on treatment systems is reduced. A possible third benefit results from the dampening of a shock load to treatment systems, which may lead to more efficient operation.

In 1950, Porges (1) estimated BOD_5 and suspended solids waste loads from receiving area cleanup could be reduced by 80 percent by instituting an initial dry cleanup in plants where only wet cleanup had been previously practiced. In gross terms, BOD_5 and suspended solids were reported to be reducible from 0.45 kg to 0.09 kg each per 1000 broilers processed. These figures have been repeatedly cited in more recent literature (eg., 6,18,24).

The 1967 study by the FWPCA (7) stated BOD_5 reduction by 127 kg/year could be achieved by implementing dry cleanup practices. However, the authors did not elaborate on the basis for their estimate. It would seem this figure could vary significantly with the size of the plant in question.

No other recent studies measuring waste loads from the receiving area were found, nor were any studies of waste loads from coop washing discovered. As it is likely that the U.S. plants Porges studied in 1950 were not washing coops, the waste load

figures he presented would be low estimates of the BOD_5 and suspended solids from the receiving areas of Canadian plants.

In the past, some poultry plants stored birds for several days before slaughter. Obviously, the longer birds are held in the plant, the more manure must be removed. Although storage of poultry is rarely practiced now, if at all, the length of holding time before slaughter varies. Some plants may be able to schedule deliveries of live birds to bring holding time down to nearly zero. However, this ideal situation is not always practical. Where trucks must drive long distances over poor rural roads in cold weather, tight scheduling could result in unforeseen breaks in production.

A.1.4 Killing and Bleeding. Federal Humane Slaughter Regulations (36) require poultry plants to slaughter by severing the jugular veins and carotid arteries either manually or mechanically. First the birds are rendered unconscious by passing their heads through electrically charged liquid or across an electrical plate. Besides fulfilling legislative requirements for humane slaughter this stunning ensures an accurate incision and minimizes blood splattering from flailing carcasses. Hanging from the overhead conveyor, the birds drain of blood.

A very small proportion of plant water use may be expended on the killing operation. If a water or brine stunner is used, continuous low flow is required. Estimates of the water volume for stunning were not found. Plants killing the birds mechanically may wet the neck feathers, to improve the accuracy of the incisions, and the efficiency of bleed out. In one case for which figures were published, 15 L/min were required.

Some general suggestions for water conservation are:

- Experiment with water inputs to the stunner and automatic killer, to determine the minimum flow necessary.
- Explore the possibility of using recycled water in the stunner, if permitted by Agriculture Canada.
- Make sure all stunning and killing equipment are well maintained.

Most of the literature on killing and bleeding addresses two related areas, maximizing bleed out and minimizing the blood lost to the sewer.

Plants should attempt to drain poultry of as much blood as possible. In a high quality product, blood is undesirable. Inadequately bled birds may show discoloration on the wing tips and elsewhere if the birds are agitated before blood pressure reaches zero (37). Maximizing bleedout also maximizes the potential volume of blood which can

be recovered, rather than entering plant effluent. Blood is often a valuable recoverable byproduct. However, it can add cost rather than revenue if it ends up in the wastewater, because blood is very high in BOD_5 .

Younger, smaller birds contain proportionately more blood than older, larger ones (38). Published sources differ on the exact numbers, but generally the figures cited ranged from 7 to 8 percent of total body weight (1,6,18,24,37,38,39,40,41). Though many sources cite figures, most refer back to Porges, 1950. Porges (1) estimated the drainable blood from 1000 chickens contributes 7.9 kg BOD_5 to a plant's pollution load. In practice not all of the drainable blood can be collected. The actual amount of blood that is recovered is affected by the age, sex, type of bird, conditions in its upbringing, stunning technique, killing technique, and bleed time. The literature is often contradictory on exactly what set of conditions will maximize bleed-out (38,40,42,43,49).

In any case, it is known that blood exerts an extremely high BOD_5 , and the more blood that can be kept from the sewer, the lower the plant's pollutional load. Available studies have placed the BOD_5 of blood at 92 000 to 100 000 mg/L (6,8). It has been estimated that BOD_5 can be reduced by up to 6.8 kg/1000 birds if careful collection is practiced (6).

In a recent study (39) a blood collection system was installed at a plant where blood had previously been sewered. About 51.1 L of blood per 1000 birds was recovered. Using 92 000 mg/L as the BOD_5 of blood, 4.7 kg of BOD_5 /1000 birds was kept out of plant effluent.

To ensure blood collection, there are several steps a poultry processor can take:

Birds must be properly stunned. There is no consensus in the literature (38,40,42,43,44) over the best stunning technique for maximum bleed-out. Some studies have produced clearly contradictory results. However, birds that have been immobilized will drain blood into a smaller and more clearly defined area than birds that flail after slaughter. Plate stunners have been found inconsistent; the birds' heads sometimes do not make proper contact with the plates. Brine stunners may not work well, because scales on the poultry feet may act as insulators. A fine mist of water sprayed on the feet of the birds immediately prior to the stunner ensures proper contact. One study recommended a brine stunner operating on a D.C. circuit at 90V for maximum bleed-out (40,42).

Bleed times must be adequate. There are conflicting reports on what constitutes an adequate bleeding time. In the one issue of a trade journal, two articles recommended different times for "best" bleed-out (100 - 150 seconds vs. 90 seconds) (37,40). Agriculture Canada inspection regulations require a minimum of 90 seconds bleeding time (34). In general, the longer the bleeding time, the more blood drained. However, the value of blood recovery must be weighed against the possibility of increasing difficulty of feather removal with a too-long bleed time (6). On the other hand, one poultry processor attributed his success at feather removal in part to a long bleed time (45).

The bleeding area must be properly designed and maintained. Bleeding must be done in an enclosed area that does not allow blood to flow or splatter into waste streams flowing to drains (drains in the collection area should be sealed). The bleeding area must be such that it can be cleaned easily with little water. It is extremely important to maintain the area so that blood does not seep through cracks or joints and eventually wind up in a waste stream. The most common bleeding area design is a long narrow room with smooth nonporous walls and floors. Recently attempts to design more efficient blood recovery areas have been made. High-walled narrow troughing or catch basins can contain blood in a much more limited area than can a bleeding room. Cleanup is easier, safer, and quicker, and less water is required for a final rinse. Automated systems have been devised to reduce the labour required to shovel or vacuum blood out of a bleeding trough or catch basin. Vacuum systems can automatically transfer blood to collection tanks or trucks (see references 14, 20, 39 for detailed descriptions).

Troughing should be installed wherever possible. After the birds have left the bleeding area, remaining blood can drip from the birds and enter waste streams. There appears to be no way of preventing this blood loss to sewer, and its consequent addition of BOD₅ to the waste load. However, plant management can attempt to pinpoint locations where blood reaches waste streams between these processes, and collect the blood with troughing. For instance, there should be no space between the bleeding area and the scalding where blood can drip onto the floor. Troughing can be installed underneath the bleeding birds, and the blood can be squeegeed into containers at breaks and after the production shift.

Cleanup procedures must be as conscientious and as dry as possible. Proper cleanup is crucial in any area where blood is collected. Blood is highly soluble. As soon as it comes

in contact with water it begins to impart BOD₅, which is difficult to remove at the "end of the pipe". Plants usually shovel congealed blood into containers, or use a vacuum system. For some plants, this is a second use for their lung gun vacuum pump. When most of the blood has been collected, more can be squeezed off of bleeding area surfaces, perhaps with a small amount of water. If the final washdown is accomplished with very little water under high pressure, the mixture may be added to the collected blood rather than being sent to the sewer.

A poultry processor can be impeccable in its blood recovery methods, but then fall down at the last step. If collection tanks or byproduct trucks leak, the blood will eventually find its way to the sewer. A study at one plant found discharge from the offal truck to carry a BOD₅ concentration of 7050 mg/L (46).

In Canada and the U.S., few poultry plants can afford not to recover blood. Increasingly stringent effluent control regulations have resulted in high costs, either for in-plant treatment systems or municipal overstrength surcharges. According to a U.S. Department of Agriculture survey, 14.2 percent of plants did not recover blood (41). Similarly, a 1974 inventory (18) of Canadian plants found 14 percent of large plants and 36 percent of small plants did not save blood. It is likely that even fewer send blood to sewer nowadays.

Blood is an asset to many processors. It may be rendered on-site or sold to an independent renderer (see (2) for byproduct utilizing options). Other plants without rendering facilities or a market for blood, consider it a liability. As at Checkerboard Foods Ltd. (Section 4.2), the plant must pay to have the blood hauled away for disposal. Effluent regulations may leave a processor no other choice.

A.1.5 Scalding. Scalding relaxes the feather follicles of poultry and facilitates defeathering. The most common technique in both Canadian and American plants is immersion. A secondary effect of the immersion is an initial bird wash. Although some sources refer to two kinds of immersion scalding, hot and warm (or hard and soft), there are actually three types: "hard" scalding at 71.1°- 82.2°C, primarily for waterfowl and thus not commonly used; "subscalding" at temperatures from 58.9- 60°C for 30 - 75 seconds, the common technique in Canada; and "soft" scalding (or "semiscalding"), typically used in the U.S., which involves immersion for 90 - 120 seconds at 50.6 - 54.4°C (42).

The main difference between soft scalding and subscalding is that the former leaves the yellow cuticle layer of skin intact and the latter prepares the cuticle for easy

removal in defeathering machines. The choice of a technique is dictated primarily by arbitrary consumer preference. In the U.S., yellow birds (with the cuticle left on) are considered desirable, and in Canada whitish birds are preferred. Scald technique affects feather removal water use.

Scalders require initial tank fill-up and continuous make-up. In the U.S. approximately 1 L (0.25 U.S. gal) overflow per bird is required under federal inspection standards. In Canada the requirement is an "adequate overflow of scalding water (47)". Table A.6 summarizes reported water use at three U.S. and one Egyptian plant with immersion scalders.

Several suggestions have been made for saving water in the scalders. Most obvious is to avoid excessive overflow, and whenever possible to turn off make-up lines during lunch and coffee breaks (48).

Noting that regulations specify the rate of continuous overflow, not continuous make-up, College Hill Poultry in the U.S. practices a unique way of conserving water in the scalders. Their measurements have found that the birds themselves each carry about a litre of water out of the scalders. That water is designated "overflow". A level control automatically opens the make-up valve when the scalders water drops below a set level. Other plants, College Hill argues, are overflowing twice the necessary volume of water (45).

A more common suggestion for water conservation is to input recycled rather than potable water to the scalders. As the U.S. EPA has pointed out (41), the scalders receives relatively dirty poultry, which subsequently are given several thorough washes. Moreover, scalders temperatures do not encourage the growth of common bacteria. A relatively clean nonpotable source, such as screened prechiller overflow may be satisfactory for make-up water. Because prechiller water has been warmed by heat loss from the poultry, it is generally no colder than the potable cold water supply. This practice is not acceptable under Canadian regulations.

Carawan *et al* (14) reduced potable water input to the scalders at the Gold Kist plant by 121 L/min from 151 L/min to 30.3 L/min by using screened prechiller overflow. A special study for the same project concluded that whole bird wash water is also microbiologically suitable for scalders make-up. Its advantages over chiller water are its lower fat content and warmer temperature.

A U.S. EPA sponsored study in an Egyptian poultry processing plant recommended reuse of compressor cooling water in the scalders. Although there was slight

TABLE A.6 REPORTED SCALDER WATER USE AND EFFLUENT LOADINGS PER UNIT PRODUCT

Source	Type of Plants	Daily kg LWK	L/bird	L/kg LWK	Wasteloads in kg/1 000 birds			Wasteloads in kg/1 000 kg LWK		
					BOD ₅	SS*	Oil & Grease	BOD ₅	SS*	Oil & Grease
Woodard, et al., 1972 (15)	72 000 broilers/day assume 1.59 kg/bird	114 480	2.2	1.4	2.0	1.8	0.04	1.2	1.1	0.03
Carawan, et al., 1974 (14)	69 200 broilers/day	114 568	1.1	0.69	1.0	0.7	0.3	0.58	0.4	0.19
Woodard, 1976 (23)	90 000 birds/day	142 882	2.7	1.7	1.6	2.4	0.14	1.03	1.55	0.08
Hamza, et al., 1977 & 1978; Witherow, et al., 1978 (26,27,28)	13 083 birds/day	14 400	5.5	5.0	5.4	-	0.38	4.9	-	0.35

* Suspended Solids

contamination by ammonia due to leakage from the compression cylinders, the water was quite similar to potable water in its trace metal and bacteriological content (26).

In the 1974 inventory of Canadian plants (18), one processor reported use of condensor cooling water for scalding make-up. Canadian plants considering use of recycled water in their scalders should ascertain the acceptability of their plans to Agriculture Canada.

Rather than being sent to sewer, scalding overflow may be put to additional use. A heat exchanger can be used to recover heat from scalding overflow, using it to warm make-up water (41). A heat exchanger is marketed for this purpose (Appendix B).

Scalding water is an inevitable contributor to the BOD₅, suspended solids, and grease in poultry plant wastewater. Blood, feathers, manure, dirt, and fat from the recently slaughtered birds all enter the hot water bath.

Table A.6 summarizes reported waste loads from immersion scalding at three U.S. and one Egyptian plant. Comparison of the data in Table A.6 with that in Table A.3 (overall plant waste loads) reveals that the scalding contributes between 3.8 and 16.6 percent of the total plant BOD₅; 4.0 to 15.5 percent suspended solids; and 0.4 - 10.9 percent oil and grease.

Emptying the scalding tank after production may exert a shock load on the treatment system, causing inefficient operation. The literature provides no suggestions for reducing waste load in immersion scalding effluent. However, one study indicated that scald water additives (to aid in feather removal) may increase the total pollutants entering into solution, thereby reducing the treatability of scalding waste water (49).

The common practice of immersion scalding has been criticized as water consumptive, heavily polluting, and unsanitary. Alternative methods to loosen feathers, such as spray or steam scalding, or microwave treatments, have been suggested. Microbiological cross-contamination has been shown to occur in immersion scalding, even in birds on which no incision has been made. Contamination can enter through the lungs and pass from there to the circulatory system (50).

Although spray scalding is less apt to transfer contamination among poultry, it is highly water consumptive. Spray scalding systems with recycle may use less water than conventional immersion scalders, but defeat the purpose of reducing contamination.

Steam scalding has been used commercially on a small scale. Because cuticle removal is not practiced in the U.S., experiments conducted there with steam scalding have used cuticle retention as a criterion to judge a system's effectiveness (51,52,53,54).

The temperature in steam scalding at atmospheric pressure has been found difficult to control, resulting in partial removal of the cuticle layer (52). In Canada, poor temperature control could result in incomplete removal of the cuticle. In sub-atmospheric low-pressure steam scalding, temperature is more easily regulated. However, experiments thus far have required manual transfer into and out of the vacuum tank, making the system impractical for most commercial facilities.

In addition to higher microbiological quality, the advantages of steam scalding, if perfected, are lower water requirements and lower pollution loads. Moreover, defeathering could be accomplished with less water (51,52). However, these conclusions are based on the U.S. experience. It remains to be proven adaptable to the Canadian industry.

Microwave "scalding" shows promise for reducing contamination, water consumption, and wasteload. The procedure, which is in an early experimental stage, would vastly reduce water consumption and waste loads by allowing feathers to be removed without any water (55). Reported experiments (56) using microwaves for feather release show promise, but indicate substantial work is needed before the technology is commercially applicable. One complication is that torso feather tracts and extremity feather tracts have different microwave energy requirements for feather release without cooking. A method would have to be devised to expose the torso to microwave while shielding the extremities, then remove the shielding and expose the whole bird. Another complication is that exposure times and power requirements vary with the weight of the bird. Workers in the field (56) have suggested that on-line minicomputers would be necessary to calibrate microwave exposure for each bird.

A.1.6 Defeathering and Feather Transport. Defeathering usually is accomplished by abrading feathers from the scalded poultry. The hanging birds pass through one or more machines with rubber "fingers" mounted on rotating drums or cylinders. Abrasion is accomplished by the friction and pulling action of the fingers against the poultry carcass. Less commonly used are batch defeathering machines, which require the birds be removed from the hanging conveyor and placed in the machines. The extra labour generally makes this method uneconomical.

Water is used in defeathering operations to lubricate the birds, thereby preventing damage and minimizing feathers sticking to the carcasses; to rinse the feathers off the birds and out of the machines; and to transport the feathers away from the processing area.

In Canada, where poultry are stripped of the cuticle layer, more water may be required for lubrication than in the U.S., where the cuticle is retained. The skin surface of subscalded poultry is sticky and tends to discolour if dehydrated (43). Inadequate lubrication in the defeathering machines may result in loose feathers clinging to the birds and unsightly blotches on the skin. This contention has not been systematically tested, but tended to be borne out by the demonstration project at Pinecrest Foods Ltd. (Section 4.1).

Reduction of water consumption may be effected by more efficient application of water in the defeathering machines. Generally, water is applied through drilled pipes running along the tops of the machines. Proper nozzles may supply more efficient application at lower volumes. The Gold Kist Study (14) achieved successful water use reduction and improved removal of feathers from the machines in this way. Vee Jet 1/8 U6510 nozzles (Spraying Systems Co.) directed downward onto the picking fingers were used. The sprays did not contact the birds directly, so the system would probably be inappropriate in Canadian plants with subscalded poultry. Attempts to use various similar types of nozzles, but directing them at the birds proved unsuccessful in the Pinecrest and Checkerboard Plants. Although water use was reduced, there were problems with loose feathers sticking to the poultry skin (Pinecrest) and deterioration of the rubber fingers (Checkerboard). This is not to say that reduction of flows to defeathering machines is not possible in Canada. Rather, further study is required to determine what nozzle type and direction, if any, will reduce flows and lubricate the poultry sufficiently.

Water consumption can be greatly reduced by installing a recycling system in plants that use potable water to flume feathers. The inventory of Canadian plants in 1974 (18) found that 52 percent of all large plants and none of the small plants surveyed recycled feather flowaway water.

Design of the defeathering cabinets and flowaway trough itself may affect the volume of water needed for feather transport. The defeathering machines may require addition of angled metal skirting to slide the feathers downward and direct them into the trough (14). Off-the-floor troughing would allow a steeper gradient than an in-floor trench, and reduce the water volume needed to move clumps of feathers. Floor trench flowaway systems may be lined with a smooth material that reduces friction. The outlet of any recycle line should direct water straight down the center of the flume to provide an effective flow for transport. Bends and angles along the flowaway can cause clogging.

If the design of the feather flowaway and the defeathering machines cannot be further improved, and feather transport is still a problem, recycled water may be used. Often the most readily available is scalding overflow. In some cases scalding overflow can be directed into the head of the feather flowaway trough by gravity (41), sparing the expense of a pump. Water from other sources, such as chiller overflow, will generally need to be screened and pumped.

The pollutant load from defeathering operations has not been measured, likely because of the physical difficulties of collecting wastewater from defeathering machines. Instead, studies have measured the waste load in feather flowaway troughs, which are more accessible. The tributary effluent streams sent to the flowaway differ, so similarities in waste loads among plants cannot be expected. The time of day of sampling can also contribute to variations if flowaway water is recycled. The water can be expected to increase in concentration throughout the day. Nonetheless, it is generally understood that the feather flowaway carries a high pollutorial load, especially BOD₅ and suspended solids. Two studies have found the feather flowaway to carry heavier BOD₅ loading than the evisceration trough (14,26,27,28).

Plants that need to pump wastewater before it is screened run the risk of increasing the strength of their wastewater. Pumping breaks up large solids, increasing the surface area and providing greater opportunity for the solids to impart pollutants to the wastewater. Furthermore, the smaller pieces may be less easily screened than larger ones. A poultry plant in Texas measured the following levels in flowaway water (32):

	Before Pumping (mg/L)	After Pumping (mg/L)
BOD ₅	295	370
Suspended Solids	325	370
Grease	110	125

Feathers impart most of their BOD₅ within a few seconds of entrance into a waste stream. Similarly, feathers can quickly contribute a high TKN load to plant effluent. Recent concerns about water and treatment costs have encouraged the poultry industry to explore alternatives to feather flowaway systems. Initially, flowaway systems were introduced as inexpensive, labour saving devices. Now, with rapidly increasing water and sewerage costs, their economy is diminishing.

Ideally, non-flowaway systems which do not revert to old labour intensive methods will be developed. A Swedish firm, A.B. Agentor, has proposed such a system, using pneumatic transport. A belt conveyor running underneath the defeathering machines carries feathers to a crusher. Water from the defeathering machines runs off during transport (a mesh conveyor belt might be used to separate the feathers from the water as rapidly as possible). The crushed feathers are moved into a blowgun, which automatically blows the feathers to rendering cookers or collecting tanks. This system has been used in Scandinavia, and one is being installed in Iraq. According to the information available, no such system is in use in North America (57).

A.1.8 Bird Washing. Agriculture Canada Health of Animals Branch requires a minimum of two spray washes of poultry carcasses, one prior to evisceration, the other before chilling. The Meat Inspection Act states: "Water spray washing equipment with sufficient water pressure to wash carcasses thoroughly and efficiently shall be used for washing carcasses inside and out" (34). Neither Canadian nor American regulations specify volumes, pressures, or other design information as to what constitutes an acceptable bird washer. This allows industry vast flexibility and latitude, but does not provide guidance for innovators attempting to design bird washers to conserve water.

The Gold Kist Study (14) found that two bird washers (whole and final) consumed 280 658 L/d, 11.5 percent of total daily processing water (excluding cleanup shift). However, the wide variety of bird washers used in the industry may limit the applicability of this figure to other plants. Nonetheless, bird washers may often consume a sizeable proportion of production shift influent. Attempts have been made to design bird washers using lower volumes of water (14,58,59).

Effective bird washers are essential to product wholesomeness. Feathers, dirt, manure, and blood left on poultry skin may harbour harmful microorganisms. Contamination of one bird may infect others during immersion chilling, or via employee hands, implements, and equipment.

A number of variables may be manipulated, in the design of a bird washer, including water volume, temperature, pressure, spray direction, spray pattern, and distance of spray from the birds. A study by Hamza, et al (59) looked at the effect of each of these variables on washing effectiveness and water conservation. Volume was found to be the most important factor in achieving bacteria removal, but also the relationship between water use and bacteria removal was characterized by a "die-away" function. As successive increments of water are applied, each one is relatively less

successful in bacteria removal. The first litre of water removes the greatest proportion of bacteria, the second litre removes a smaller proportion, and so on. Added nozzle pressure was found to improve bacteria removal by about 2.5 percent for each 103 kPa between 276 and 1724 kPa, but only in the first increment of wash water. That is, improvement is seen in the first litre of water applied, and additional litres of water are extraneous. Pressures above about 586 kPa were found to potentially force bacteria into the poultry skin. Above 1100 kPa pressure and at water temperature of 45°C and warmer, poultry skin became unacceptably sticky and glossy. High temperatures combined with pressures of 276 kPa and higher caused fat loss. This diminishes product value and adds to the plant waste load.

Flat sprays proved most effective in bacteria removal at low volumes. The nozzles could be placed at a distance from the birds that allowed virtually all of the water to contact the carcasses. No additional bacterial removal occurred when carcasses were rotated as they passed through the wash cabinet.

In conclusion, the study by Hamza, et al recommended construction of a two-stage countercurrent prototype washer. The first stage would spray water at 45°C through flat spray nozzles at 552 kPa. In the second stage 20°C water would be sprayed at 276 kPa. No number or configuration of nozzles was recommended, but projected water use through the prototype bird washer would represent a 50 percent reduction over conventional washers.

Researchers at the U.S. Department of Agriculture have designed a bird washer that is intended to effectively clean poultry while minimizing water use (58). Thirty-two flat spray nozzles at 138 kPa are used for a double line of poultry, and 1 L/bird is consumed at 14.4°C. The designers indicate this to be a water saving of over 50 percent per washer. Sprays are all directed horizontally onto the carcasses, and clean the top (hocks) first, moving to lower portions as the poultry pass through the cabinet. A key to the washer's effectiveness is the maintenance of pressure at 138 kPa. Bacterial reduction was not nearly so great at lower pressures. A small booster pump is recommended, along with a pressure regulator to ensure sufficient uniform pressure.

The Gold Kist study (14) modified both whole and final bird washers, cutting water use on the former by 19 percent and the latter by 40 percent. In both cases nozzle sprays replaced a drilled pipe arrangement. The whole bird washers were equipped with two horizontally placed pipes, one on each side of the birds. Each pipe used 16 nozzles. Many nozzles and showerheads were evaluated. Showerheads actually increased water use

over the drilled pipe washers. The Vee Jet, Type V No.1/4-U6510 and No.1/4-U6515 (Spraying Systems Co.) were selected and operated at 83 kPa.

The final bird washer at Gold Kist was designed differently. It used vertically, rather than horizontally mounted pipes and was operated at 55 kPa. Nozzles chosen were also Vee Jets, but much more water consumptive models than those selected for the whole bird washer. No rationale for the contrasting designs was supplied.

The research currently available on what combination of characteristics produces an effective, low-volume wash system is meagre and contradictory in its recommendations. The systems designed for the two Canadian poultry plant demonstration projects in this study were modelled on the U.S.D.A. system described above, but were not particularly effective in removing visible evidence of contamination. Part of the problem may have stemmed from the sticky skin characteristic of Canadian subsalded poultry. Another problem was the difficulty in maintaining proper pressures.

At this early stage in the development of low water use washers, a plant might be best advised to attempt some modest experimentation. For instance, a gradual reduction in total volume used by the washers may produce an equally acceptable product if water use has been excessive. Showerheads and drilled pipe washers can be replaced with more efficient nozzles. Nozzle number and/or configuration and/or aim may have to be altered to ensure adequate spray coverage on the carcasses.

Instead of (or in addition to) modifications of bird washer design, water may be consumed in this area by reusing the effluent for another purpose. The Gold Kist study (14) experimented with using spent whole bird wash water as make-up for the scalding. It was concluded that the whole bird wash water was preferable to chiller overflow for use in the scalding, because it contains less grease, solids, and BOD₅, and because of its warmer temperature.

The Gold Kist study also concluded that using a combination of chiller overflow and final bird wash water to flush gizzards in the splitting machines does not negatively effect the microbiological quality of the gizzards.

Canadian plants could not institute such recycle programs without permission from the Health of Animals Branch of Agriculture Canada.

Wastewater concentrations (mg/L) in bird washer effluent at the Gold Kist plant before modifications measured:

	Whole Bird Wash Before/After Changes	Final Bird Wash Before/After *
BOD ₅	108/29-91	442/489
Total Solids**	226/130-318	667/575
Grease	150/21-50	580/90

Concentrations may be stronger at low volumes, especially at high pressures. It seems plausible that the more effective the bird washer, the higher the gross pollutant quantities. If a bird washer removes useable product as well as unwanted contaminants waste loads will be excessive. Grease particularly will increase as more fat is forced off the birds. Higher temperature will also induce fat loss.

A.1.9 Evisceration. Although the evisceration processes do not involve direct application of water to the bird, the evisceration area is highly water consumptive. Water is used to maintain cleanliness of equipment and employee hands, for fluming inedible byproducts, and for giblet processing and transport. Wastes from the evisceration area may contribute a sizeable proportion of the plant's pollutant load.

The water used per unit product can vary enormously from plant to plant, depending on the equipment used and the habits of employees. Automatic equipment, such as eviscerators, and semi-automatic equipment, such as vent guns, consume small amounts of water to rinse parts coming in contact with the poultry. Vacuum equipment, such as lung and kidney guns, also use water in the vacuum pumps. Most of the water is used in four areas: employee hand and implement washing, sidepan wash for troughing, gizzard processing, and giblet transport.

In many plants, goosenecks flow continuously for the rinsing of worker's hands, knives and scissors. At the Gold Kist plant (14), gooseneck flow accounted for almost one-quarter of all water used for processing. Based on published descriptions, plant visits, and communication with industrial sources, the Gold Kist experience appears typical.

* These figures represent measurements after settling and screening.

** Total solids, rather than suspended solids, are used in this table to facilitate comparisons. Suspended solids had not been measured for the whole bird wash after changes. Before changes, suspended solids = 81 mg/L. In the final washer, before changes, suspended solids = 287 mg/L; after changes, suspended solids = 130 mg/L.

Several steps may be taken to reduce gooseneck flow, either individually or in combination:

- Regulate gooseneck pressure. High pressures cause splashing and fogging. Too low a pressure will mean greater water requirements. The Gold Kist study recommended 55 kPa.
- Install nozzles on the goosenecks. A given volume of water can be applied much more efficiently and effectively with a nozzle than without. Experimentation at the Gold Kist plant resulted in the recommendation of Full Jet, No.1/4-HH6.5, 3/32" nozzles (Spraying Systems Co.).
- Install flow controls. Flow controls can be preset to allow a precise volume flow rate when valves are opened full. They can prevent abuse of a water conservation program.
- Install body-activated valves. They can save a great deal of water at stations where hand washing is infrequent. Where hand washing is frequent, such as in giblet harvesting, body-activated valves may slow down the line and induce fatigue. Foot activation is not recommended, as it is more fatiguing than hip or knee control, tends to make cleanup more difficult, and the controls are vulnerable to breakage during cleanup.
- Consider "tickler" valves or hand activated valves which operate by pushing a small "joy-stick" at the outlet end of the gooseneck. Some of these are fashioned such that the activator is rinsed while the hand is washed. They are inexpensive and easy to install, but some may not be as "self-cleaning" as is desirable for proper sanitation. Employees may find two hands are necessary for thorough washing, an inconvenience on a rapid line.

The sidepan wash often used at plants with metal flowaway troughing may use large volumes of water rather ineffectively. It is typically a drilled pipe arrangement which allows water to trickle down the sides of the evisceration trough, intended to keep the troughing clean. It serves the additional purpose of assisting in offal flowaway. At the Gold Kist plant (14), the sidepan wash was found to use 7.5 percent of total processing water.

Plants intent on conserving water may wish to consider eliminating the sidepan wash entirely, as was done at the Pinecrest plant (Section 4). A less drastic measure is to improve the system by regulating pressure and installing a timer to activate the sidepan wash periodically (14). If the sidepan wash is retained, it should not share a supply line

with the goosenecks because the sidepan wash requires much greater pressure than do the goosenecks (14). Another alternative is to dispense with metal evisceration troughing, and use an in-floor trench for offal flowaway. This innovation has been tried by a few plants. An in-floor trench needs no sidepan wash, is not subject to leaks, and cleanup is quicker and easier (60).

Gizzard processing is an extremely water consumptive operation, and few suggestions are available for conservation. The water is required to flush grit and fat from the gizzards after they are split, and to peel the lining on gizzard peelers. There appears to be no alternative to using large quantities of water for flushing and peeling. Use of recycled water as a partial or total replacement for potable water has been suggested. Although a pilot study found no deterioration of microbiological quality when a combination of chiller and final bird wash water was used as input for gizzard processing, more studies would be desirable for confirmation (14).

The other water use in giblet processing is for transport away from the evisceration area to chilling or packaging. Some plants use small flow troughs, while others use pneumatic transport systems, which are less water consumptive.

Giblet flow troughs should be designed with as steep a gradient as possible to minimize water requirements. The possibility of reusing the transport water, or fluming giblets with recycled water, needs further study to evaluate the microbiological safety.

A two-part study indicated that giblet chiller or gizzard splitting water could be used to flume giblets without microbiological deterioration of quality (61,62). First, microbiological quality of four process waters - gizzard splitter, final bird washer, giblet flume, and giblet chiller - were compared. Gizzard splitter water was of significantly higher microbiological quality. Giblet flume water was of poorest quality. Second, the microbiological condition of giblets after fluming and after chilling was determined. Although the two process waters were of significantly different quality, the giblets did not differ significantly in either fecal coliform counts or salmonella presence. Therefore it was concluded that the quality of the process water is unrelated to its washing efficiency.

The typical poultry plant allows most of the spent process and cleansing water in the evisceration area to spill into the trough or offal flowaway. Final bird wash water also typically contributes to the offal transport. The volume is generally sufficient for moving the inedible product, so that potable water is not needed.

However, if strict water conservation measures are implemented, a plant may risk having an insufficient volume for the offal flowaway system. If this occurs, recycled water from virtually any source within the plant should be acceptable, or offal transport water could be screened and recycled back down the viscera trough. However, such a recycle proposal would have to be reviewed by Agriculture Canada.

Spent water from the evisceration area, having carried offal, contains high levels of BOD₅, suspended solids and oil and grease. Pinpointing "typical" waste loadings is not possible, due to differences among plants in the various process effluents contributing to viscera trough flow. Table A.7 illustrates some pollutant loadings reported in the literature. In most cases, the reported BOD₅, suspended solids and oil and grease from evisceration represent at least one-third of the total plant waste load. Oil and grease is a particular problem, with one plant reporting 97 percent originating in evisceration (19,20,21).

The only in-process way to reduce waste loads is to prevent the pollutants from reaching the waste stream. This, of course, is completely contrary to the purpose of a flowaway system. Plants may improve their situation somewhat by reducing water use, thus cutting down the hydraulic loading on treatment systems, or by installing better screening and treatment systems. Major reductions require the elimination of offal flowaway systems.

Pressure to reduce the water consumption and waste loads has resulted in the recent development of "dry" offal conveyance systems. The offal is automatically removed from the evisceration area, rather than being placed in containers and carted away as in pre-flowaway systems.

Dry offal systems for poultry processing are typically negative pressure pneumatic (i.e., vacuum) systems (see (19) for an enumeration of the advantages over positive pressure systems). Viscera are dropped into hoppers and periodically automatically sucked away to a collection area. The hoppers are lined with mesh to allow water to flow to a floor trench or troughing below.

There is some controversy over the amount of water actually saved by the new dry offal systems. Although the sidepan wash is no longer needed, a dry offal system has no effect on other major water uses unless a plant had been previously supplementing trough flow with potable water. The vacuum pumps for a dry offal system require a constant flow of water.

TABLE A.7 REPORTED EFFLUENT LOADINGS IN EVisCERATION TROUGHS

Source	Type of Plants	Concentrations (mg/L)			Total Waste Load				
		BOD ₅	SS*	O&G**	kg/1 000 birds BOD ₅	SS*	O&G**	kg/1 000 kg LWK BOD ₅	O&G**
Hamm, 1972 (13)	10 U.S. broiler plants	-	-	149	-	-	-	-	-
Woodard, et al., 1972 (15)	72 000 broilers/day assume 1.59 kg/bird	363	371	208	5.7	5.9	3.3	3.6	2.1
Carawan, et al., 1974 (23)	69 200 broilers/day	233	302	430	-	-	-	-	-
Frost & Woodard, 1975; Woodard, 1976 (22,23)	90 000 birds/day	520	360	500	7.6	5.3	7.3	4.8	4.6
Whitehead, et al., 1975 a&b, 1976 (19,20,21)	2 evisceration lines (@ 4 800 birds/hour assume 1.59 kg/bird conventional dry offal)	-	-	-	22.9	9.7	19.6	14.4	12.3
Whitehead, 1976 (46)	9 600 birds/hour	1 522	430	962	5.5	2.2	2.4	3.5	1.5
Hamza, et al., 1977 & 78 (26,27)	Figures include giblet processing	1 156	-	208	3.0	-	-	2.7	-

* Suspended Solids

** Oil & Grease

A recent U.S. EPA survey (24) found that the two chicken processing plants reporting dry offal systems used lower than average water volumes. On the other hand, the one turkey processor with a dry offal system had an average water use volume. A recent study installed a dry offal system on one evisceration line, while a conventional offal flowaway was left on an identical evisceration line. The flow down the conventional trough was 836.6 L/min, while the "dry" system still produced 741.9 L/min, an 11 percent reduction (20).

A Utah turkey plant combined a dry offal system with a gooseneck water scheme to reduce water use dramatically. The plant previously used 160 goosenecks at 15 to 23 L/min each. The plant doubled its 363 000 kg/d production, installed a dry offal system, and began the gooseneck water reuse scheme. Goosenecks flow into basins, which drain to a diatomaceous earth filter system. Filtered water is chlorinated and then reused. A savings of more than 1500 L/min water was reported (63).

Dry offal systems have a much more substantial effect on waste loads. In one documented case evisceration wastes were reduced by 75 percent for BOD₅, 78 percent for suspended solids, and 77 percent for oil and grease (20).

A.1.10 Chilling. The microbiological safety of various poultry chilling methods is a source of current controversy. It is beyond the scope of this study to review the great mass of literature on the relative merits of chiller types and operation methods. Instead, a very brief summary is presented relating to water use, and references are provided for the reader who wishes to explore the subject in greater detail.

In retrospect, the controversy that developed in Europe following a European Economic Community (EEC) directive banning spin chilling systems stemmed, as much as anything, from a difference in semantics. In Europe, some chilling systems had been operated unhygienically, and these were called "spin chillers". In North America, however, the term "spin chiller" referred to systems operating under careful in-plant and governmental regulations (64).

Nonetheless, questions have been raised about the operation of immersion chillers, particularly the amount of potable water necessary to produce a microbiologically acceptable bird. The major objections concern the potential for cross contamination and uptake of contaminated water into poultry tissue. The EEC Code of Practice sets more stringent operational rules than do Canadian or American inspection regulations, including a minimum requirement of 2.5 L of water per kilogram of poultry (versus the

U.S. requirement of 1.89 L/chicken, and the Canadian requirement of a continuous overflow).

Some studies have shown microbiological improvement after chilling, whereas others have shown deterioration. The majority opinion (although by no means unanimous) is that carefully controlled hygienic operation of immersion chillers improves microbiological quality by its washing effect.

There is also contradictory evidence as to what constitutes "proper" operation. At one extreme is the EEC Code of Practice, with its large makeup water requirements. At the other is the evidence of one U.S. poultry plant that, under supervision by the USDA, experimented with reducing the addition of potable makeup water to only that provided by addition of ice, and found no deterioration, as measured by turbidity (45,65).

Besides stimulating research and discussion about immersion chilling operation, the EEC directive had the effect of encouraging research on alternative chilling methods. Alternatives suggested include:

- spray chilling,
- cold air or gas chilling,
- evaporative (vacuum) chilling,
- chilling by metal contact.

The two latter methods are generally dismissed as not technologically developed to the point of commercial viability. Spray chilling, developed in Germany, was unsuccessful commercially because of a 12 L/bird water requirement (64).

Air chilling has been successfully used in commercial operations, to a limited extent in North America, and on a large scale in some European countries. However, air chilling is limited to poultry which has been soft scalded and is to be marketed fresh. Air chilling has the distinct disadvantage of producing a final product that weighs about 5 percent less than conventionally chilled birds. There has been contradictory evidence on whether or not air chilling produces a microbiologically safer or less safe product than immersion chilling (66).

It appears that the most commercially viable chilling method is still immersion chilling. The reader wishing to acquire more information on chilling methods is referred to (64,67-96).

Canadian inspection regulations do not specify a rate of addition of makeup water to the chiller, nor are any sizes or particular types of chilling equipment specified.

However a continuous overflow is required, with details of the operation left to the inspector-in-charge.

American inspection regulations specify a makeup water rate of 1.89 L (0.5 U.S. gal) per bird, and require water meter readings as records. For this reason, most studies on water conservation done in the U.S. treat chilling superficially or not at all. Little data is available on chiller water consumption, except the water required for initial filling (which varies with different equipment), plus 1.89 L makeup water per bird, plus the water needed for ice making. The latter requirement varies with influent water temperature, whether or not the chill tanks are refrigerated, and the throughput of birds compared to the capacity of the chillers.

Canadian processors might benefit from installation of a water meter on chilling equipment. Consultation with the inspector-in-charge could lead to development of an acceptable rate of addition of makeup water, and the meter would be useful in maintaining that level. Plants should bear in mind that ice addition is, in fact, addition of fresh water, and should be incorporated into the calculations of makeup water added. To receive the maximum cleaning benefit, makeup water should be added at the point of exit of the birds and flow in the reverse direction of the movement of the birds, overflowing at the entry location. This is not possible with all commercially produced chilling systems. However, when such a counterflow is used, the poultry moves into ever cleaner water. This does not imply that chilling should be considered a washing system, but chiller water can help remove surficial bacteria or, conversely, impart contamination to the poultry.

Plants using a two-stage chilling system may conserve water by a counter-current flow main chiller to prechiller. However, a recent study in Egypt found that such a countercurrent scheme produced lower microbiological quality in both the process water and the birds (28).

Spent chiller water may be used to cool fresh makeup water, saving on the input of ice necessary to keep the temperature down. The manufacturer of a heat exchanger for this purpose (Crepaco, Inc., Chicago, Ill.) estimates a savings of up to 0.5 kg of ice per bird. However, this is based on an influent temperature of 26.7°C, higher than would often be found in Canada. Nonetheless, a poultry processor that adds large volumes of ice to its chillers might find a heat exchanger an economical addition to the plant (see Appendix B).

Chiller water could also be reused in another area of the plant (97). Using chiller overflow in the scalding or in gizzard splitting has been mentioned. Other

suggestions have been to use the spent chiller water for transport of inedible product, or to filter the chiller overflow and use it for fluming edible product. Giblet fluming has already been discussed. Similarly, filtered chlorinated chiller water has been found acceptable for fluming broiler necks (98,99). Agriculture Canada has not sanctioned the use of chiller overflow for edible product-related operations.

Waste loads in chiller effluent, like scalding effluent, are practically unavoidable in immersion chilling. Reported figures are summarized in Table A.8. The figures vary, as is common in the literature on all aspects of poultry processing effluent.

The amount and intensity of agitation, and the length of time the carcasses are kept in the chiller are both probably related to the volume of pollutants discharged. However, in most plants these parameters are determined by more crucial needs, such as proper cooling and moisture pick-up.

Most chilling systems are equipped with some sort of grease trap, which skims grease off the top of the chiller water before it overflows. One plant was observed to use a baffle running the width of the chiller, located near the exit of the birds from the chiller. The baffle served to protect outgoing carcasses from passing through a grease layer. A simple hand strainer was used to periodically remove the trapped layer of grease. It appeared to be effective not only in protecting the birds, but also in preventing some grease and solids from entering the plant wastewater (100).

Canadian inspection regulations state that giblets must be cooled to 4.4°C within two hours of harvesting. Livers cannot be placed in agitating giblet chillers, but should be placed in containers of ice or slush (101).

Limited literature is available on giblet chilling. Overall water use is not discussed, but waste loads have been reported. Giblet chiller effluent is high strength, especially in BOD₅. Whitehead (46) reported the following concentrations:

BOD ₅	-	1251 mg/L
Suspended Solids	-	236 mg/L
Oil and grease	-	170 mg/L

Carawan, et al (14) reported much higher levels:

BOD ₅	-	2360 mg/L
Suspended Solids	-	976 mg/L
Oil and Grease	-	1320 mg/L

TABLE A.8 REPORTED EFFLUENT LOADINGS IN CHILLER EFFLUENTS

Source	Type of Plants	Concentrations (mg/L)			Total Waste Load			kg/1 000 kg LWK		
		BOD ₅	SS*	O&G**	BOD ₅	SS*	O&G**	BOD ₅	SS*	O&G**
Hamm, 1972 (13)	10 U.S. broiler plants	-	-	165	-	-	-	-	-	-
Woodard, et al., 1972 (15)	72 000 broilers/day assume 1.59 kg/bird figures are o/f & dump	582	359	175	4.3	2.6	1.3	2.7	1.6	0.8
Carawan, et al., 1972 (14)	69 200 broilers/day									
	prechiller chiller	442 320	253 183	800 250	1.6***	0.9	2.2	1.0	0.5	1.3
Frost & Woodard, 1975; Woodard, 1976 (22,23)	90 000 birds/day figures are o/f & dump	-	-	-	3.5	2.5	1.6	2.2	1.6	1.0
	9 600 birds/hour	830	365	335	-	-	-	-	-	-
Whitehead, 1976 (46)										
Hamza, et al., 1977 & 78 (26,27)	prechiller	956	-	270	1.6	-	-	1.4	-	-
	chiller	758	-	239	0.7	-	-	0.6	-	-

* Suspended Solids

** Oil & Grease

*** Calculations here disagree with calculations in the report.

Applying these figures to the giblet chilling water use of 9198.5 L/d and daily slaughter of 69 200 birds per day reported by Carawan et al yields:

BOD ₅	-	0.3 kg/1000 birds
Suspended Solids	-	0.1 kg/1000 birds
Oil and Grease	-	0.2 kg/1000 birds

Thus, although giblet chilling wastewater is high strength, it is a minor contributor to overall plant effluent loadings. No suggestions for reducing the waste load from giblet chilling were found.

A.1.11 Recycle/Refuse Schemes. As concern over water in processing increases, more attention is focused on reusing process water on a large scale. Many individual process recycle possibilities have been discussed above.

An ongoing study sponsored by the U.S. EPA at the Alexandria (Egypt) Poultry Plant (APPP) has been experimenting with reusing process water on a larger scale than usual. Results reported recently have been discouraging (28). The project introduced a countercurrent flow from the chiller through the prechiller, washer (immersion type) and scalding. Before the production shift began all tanks were filled with potable water. The scalding needed addition of some potable water because its makeup requirements were greater than the washer's requirements. Using the criterion that carcass and process water quality must be at least as high as during normal (non-reuse) operation, the countercurrent scheme was unsuccessful. Statistical analysis of chemical and bacterial sampling showed that, overall, the carcasses and process water were of significantly poorer quality under countercurrent flow conditions than when potable makeup was added at each process. There was a relationship between bacterial quality of the carcasses and the process water. The next stage of the study will attempt to renovate the water between processes in a countercurrent scheme.

The Sterling Processing poultry plant in Maryland, U.S.A. has attempted what is essentially a total reuse scheme (102,103,104,105,106,110). The plant, in cooperation with various state and federal agencies, built advanced treatment facilities to totally renovate its effluent to potable quality. The objective was the continuous recycle of spent process water back into the plant. However, the project was terminated due to an EPA decision that "renovated water cannot be considered potable" (105).

A.1.12 The Effect of Attitudes on Water and Waste Management Practices. There is a strong emphasis in the literature on the importance of attitudes and education to the

success of a water conservation and in-process waste reduction programs. Most basic is an attitude of commitment to the program by management. The Gold Kist study stated:

"Every poultry processing plant should have one person who is completely responsible for the water and waste program. He should have latitude to develop the program and the authority to implement his plans reporting directly to the plant manager. He should not be overloaded with duties which would keep him from devoting at least the majority of his time to water and waste problems... Management must remember the program must be continued or it will die. Mention of the program must be frequent. The water/waste supervisor must follow the operations assuring that proper water and waste procedures are followed each operating day" (14).

However, many plants cannot justify the expense of a full-time water/waste supervisor.

Knowledge and cooperation of plant workers also play a large role in the program's success. Carawan, *et al* (14) went so far as to state, "Employees should be informed and involved in the program or it will not work".

A recently published manual on food industry water and waste management (107) written for the U.S. Extension Service summarized the words of a food processing specialist as follows:

"Top management is the place where the buck stops. The place where the motivation starts. If there is something special in a firm's accomplishments in the environmental field, it is because of the attitude of top management and not necessarily their expertise in that technical field" (108).

Observations at North American plants visited by study personnel for this report reconfirmed these assertions. At plants displaying exemplary water and/or waste management practices, management was obviously strongly committed, and seemed to take day to day interest in the program's success. On the other hand, at plants where conservation programs were relatively unsuccessful, management appeared disinterested and unknowledgeable about the programs.

The initiation of a conservation program should come from within the plant to be successful in the long run (33,109). However, the motivation may come from outside the plant, in the form of government regulations or municipal water and sewerage charges.

A.2 Water and Waste Management in the Red Meat Processing Industry

Red meat processing plants slaughter cattle, calves, hogs, sows, sheep and horses for the preparation of meat products. Individual establishments may be involved in

only slaughtering and dressing operations, or may also carry out varying degrees of meat processing such as the manufacture of sausages, and cured and smoked meat products. Some plants process only their own kill. Other plants may also process meat purchased from other plants. Most large packinghouses and many slaughterhouses also render byproducts. Smaller facilities generally send viscera, trimmings and bones to an independent renderer.

This section of the literature review deals specifically with water and waste management practices applicable to red meat slaughtering and processing operations. Rendering operations are dealt with in more detail separately in Section A.3. A schematic process flowsheet of an integrated packinghouse is shown in Figure A.2. The number of individual unit processes represented at any specific red meat processing plant will vary considerably depending on the size and complexity of the operation.

Compared to the poultry processing industry, relatively little information has been published regarding water and waste management practices during red meat slaughtering and processing. The available information is mostly presented as discussions of in-plant changes which could be implemented rather than detailed review of changes which have been implemented and the relative success of these changes. On a unit weight production basis, the red meat industry is less labour-intensive and uses less water. Few unit processes require large quantities of water for heat transfer or product washing, compared to poultry processing where such processes as scalding, feather and offal fluming and chilling use large amounts of water. Nevertheless, many opportunities exist for in-plant water and waste management in meat packing plants.

A.2.1 Water Usage in the Red Meat Processing Industry. Water is used in the red meat processing industry for cleaning the product and the facilities, conveying waste materials and for heat transfer operations such as hog scalding, refrigeration and heating. The amount of water used in any particular plant will vary with the age, size and complexity of the plant, as well as the attitude of plant management toward water conservation and the relative costs of water and waste disposal.

The inventory of the Canadian meat processing industry (18) produced minimal data on water usage. Water use is generally presented on a unit production basis (litres per kilogram live weight killed). Based on the data extracted from this inventory, water use in the Canadian industry was found to average approximately 15 L/kg LWK in plants slaughtering more than 2.5 million kilograms live weight per year. However, water use varied widely. Some plants reported water consumption approaching 60 L/kg LWK. In

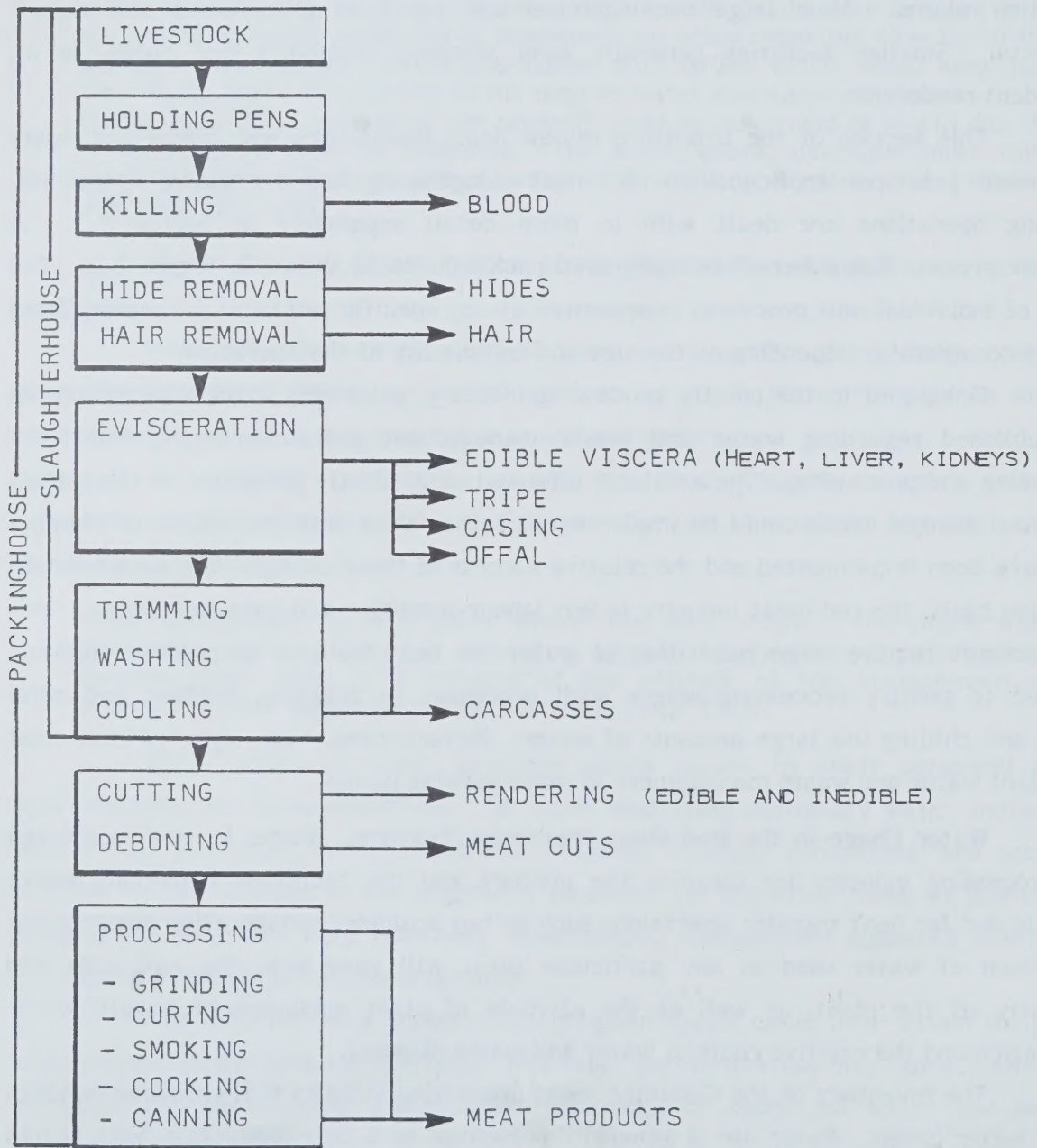


FIGURE A.2 PROCESS FLOW OF AN INTEGRATED PACKING HOUSE

similar surveys in the United States (111), water use figures in the range of 1.3 to 14.6 L/kg LWK were reported for simple slaughterhouses (average of 24 plants was 5.3 L/kg LWK). For complex packinghouses, the range was approximately 3.6 to 12.5 L/kg LWK (average of 19 plants was 7.4 L/kg LWK).

A.2.2 Waste Loads in the Red Meat Processing Industry. Red meat processing results in the discharge of grease, blood and a variety of other proteinaceous materials in the process effluents. Suspended solids, grease, BOD₅ and total Kjeldahl nitrogen (TKN) are the parameters most commonly used to characterize these effluents.

The waste load from red meat processing varies widely between plants and is generally affected by the same factors that influence water usage. A direct relationship between the quantity of BOD₅ discharged from a plant and the amount of water used per unit LWK has been reported (3). Excessive water use is probably indicative of poor control of cleaning procedures and plant housekeeping, resulting in excessive losses of blood and trimmings to the sewers.

Meat packing plants have typically been categorized by the in-plant methods used to control process effluent waste loads. Three categories - old, typical and advanced - have been defined based on the following criteria (18):

'OLD'	'TYPICAL'	'ADVANCED'
Blood Sewered	Blood Recovered	Blood Recovered
Paunch Manure Sewered	Wet Paunch Drying Manure Screened	Dry Paunch Dumping Manure Disposed
Wet Edible Rendering Tankwater Sewered	Wet Edible Rendering Tankwater Evaporated	Low Temperature Edible Rendering
Wet Inedible Rendering Tankwater Sewered	Dry Inedible Rendering	Dry Inedible Rendering
Wet Cleanup	Dry Cleanup	Dry Cleanup
No Grease/Solids Recovered	Grease/Solids Recovered	Grease/Solids Recovered

Based on these categorizations, waste loadings in terms of BOD₅ per unit production have been developed (18,111). These data are, for the most part, based on American surveys; however, they provide a sufficiently accurate estimate of the Canadian situation because processing techniques are similar. Waste loadings per unit process are summarized in Table A.9 (18). Unit loadings from rendering operations are not included.

TABLE A.9 BOD₅ LOADINGS FROM RED MEAT PROCESSING PLANTS (18)

Process	BOD ₅ (kg/1 000 kg LWK) for Plant Category		
	Old	Typical	Advanced
Holding Pens	0.25	0.25	0.25
Kill Floor	10.0	3.0	3.0
Blood Processing	Nil	1.3	0.3
Hide Processing	Nil	1.5	1.5
Hog Hair Handling	0.65	0.65	0.65
Hair Processing	1.0	Nil	Nil
Paunch Handling	2.5	1.8	0.2
Paunch Processing	1.0	1.0	Nil
Intestine Processing	0.6	0.6	Nil
Cleanup	3.0	1.7	0.3
TOTAL	19.0	11.8	6.2

No published information is available on characterization studies in Canadian plants. Data from an industry-wide survey of waste loadings in American plants is given in Table A.10.

In analyzing the waste loading and water use data, it should be emphasized that two plants of similar size and using similar process technology may exhibit vastly different process effluent characteristics. These data should be considered only as rough indicators of the characteristics which might be expected at any particular plant. The discussions relating to the validity and interpretation of published water use and waste load data for the poultry processing industry (Section A.1) are equally applicable to the red meat processing industry.

A.2.3 Holding Pens. Water usage in animal holding areas is primarily associated with cleanup operations, although adequate quantities must be provided to the animals for drinking. Pollutants from these areas consist of manure and urine, hay, straw and dirt washed to the sewers as a result of cleanup operations or stormwater runoff.

In most Canadian meat packing operations, pens are covered or completely enclosed to protect livestock from severe winter conditions. This reduces the waste load to the sewer by eliminating the flushing of contaminants in stormwater runoff.

TABLE A.10

PROCESS EFFLUENT WASTE LOADS* FROM RED MEAT PROCESSING PLANTS (111)

	Simple Slaughterhouse				Complex Packinghouse			
	BOD ₅	SS	Grease	TKN	BOD ₅	SS	Grease	TKN
Number of Plants	24	22	12	5	19	16	11	12
Average	6.0	5.6	2.1	0.68	10.9	9.6	5.9	0.84
Maximum	14.3	12.9	7.0	1.36	18.8	20.5	16.8	2.1
Minimum	1.5	0.6	0.24	0.23	5.4	2.8	0.7	0.13

* Waste loads reported as kg/1000 kg LWK.

Dry cleanup of solid waste and separate disposal is the principal management tool associated with holding pens. With adequate dry cleanup, the waste load from holding pens is approximately 0.25 kg BOD₅/1000 kg LWK (113), less than five percent of the total effluent load. Pens can be designed to facilitate dry cleanup and reduce the volume requirements for final washdown (114). Fan-shaped pens are more efficient than rectangular pens in terms of space utilization. Thus, smaller amounts of water per animal are needed for washing because floor space can be reduced. Floor slopes should be adequate to facilitate removal of residual solids to drains with minimal amounts of water, drains should be plentiful and grates should be provided to prevent gross solids from entering the sewer system. Most of these comments relate to the design of new pens. Little can be done to improve existing pens without major capital expenditures. However, efficient dry cleaning can minimize wastewater volumes and loadings regardless of pen design.

Potable water is not required for cleaning of livestock pens. Swift Fresh Meats Co. at East St. Louis demonstrated that process waters such as compressor cooling water and condensate from steam lines could be effectively used in the hog house, saving the equivalent of about 1100 L/min while the plant is operating (115).

Agriculture Canada requires that livestock be provided adequate water supply. However, continuous water addition to troughs is unnecessary and wasteful. Water should be supplied on a demand basis, preferably through level-regulating valves. Manual control of water supply can result in wastage due to carelessness.

A.2.4 Kill Area. Although water usage associated with the kill area is relatively small and primarily used to clean equipment and personnel, the waste load from this area can represent more than 50 percent of the total effluent BOD₅ load (18). This loading is primarily from blood lost to the sewers. The BOD₅ of whole beef blood is approximately 150 000 mg/L and each animal may contain up to 20 kg of blood (116).

It is obviously imperative that as much blood as possible be saved to prevent excessive wastewater disposal costs. Based on the 1974 inventory data (18), approximately three-quarters of the plants responding to a survey recovered blood. All large plants (>10 million kg LWK per year) recovered blood; however, only 60 percent of small plants (<0.5 million kg LWK per year) recovered blood.

Reduction of the waste load from the kill area involves segregating blood from the process sewers. Generally about 70 percent of the total blood content can be

economically recovered (111). The remainder will be lost during evisceration, hide removal and in spills and splatters which are wasted to the sewer during cleanup.

The amount of blood that can be readily collected on the kill platform depends on the time allowed for bleedout after the animal is stuck. The bleed area should be as large as possible. Once the animal begins to travel through the eviscerating processes, blood can be collected by curbing or troughing under the kill line. However, in many existing facilities, space is severely limited and such troughing and curbing can interfere with the evisceration process.

Blood can best be segregated from the process water sewer if a separate blood sewer is provided. During processing and cleanup, blood is swept to the blood drain. An initial low-volume water rinse of the bleed area should also be directed to the blood drain. This rinse probably represents less than 300 L depending on the surface area of the floor (117) and will not significantly affect the cost of final blood processing, even in small plants which collect up to 3000 L of whole blood daily. Final cleanup of the bleed area should be directed to the effluent sewers.

In the Oscar Mayer study (118), improvements in the blood recovery system, including modifications to troughing and more efficient dry cleanup, resulted in the collection of an additional 25 kg of blood per day, equivalent to about 4.5 kg per day of BOD₅. These changes were basically operational and involved no capital cost.

Blood collection has become very sophisticated in Europe where considerable quantities of blood are used for edible products. Hollow sticking knives connected to vacuum systems and equipped with anticoagulant feed lines have been developed which, it is claimed, improve the recovery efficiency by 30 to 40 percent over traditional open vessel collection methods (119). As Department of Agriculture regulations require that the blood of any condemned animal be condemned (34), blood for edible purposes must be identifiable with the carcass until the carcass has passed inspection. Thus, some batching of blood lots is necessary so that large quantities of blood will not be condemned unnecessarily. In Canada, where whole blood collection for edible purposes is not as extensively practised and is restricted to beef blood (34), less sophisticated vacuum collection systems could be used to improve blood collection efficiency for inedible purposes from all animals.

A.2.5 Blood Processing. Blood collected from the kill floor must be disposed if it is not marketed as an edible product. There are two basic methods available, coagulation and drying.

Coagulation of blood by injection of steam was an early development (120). The coagulated material is separated by screening or centrifugation from the liquid phase, bloodwater, and dried for use in fertilizers, animal feed, glue and pharmaceuticals. The bloodwater, containing approximately 13 percent of the BOD₅ of the original whole blood (18), is generally sewered. Few Canadian processors use the coagulation method of blood processing.

Blood drying reduces waste loads more efficiently as only a small quantity of bloodwater is discharged, representing less than three percent of the whole blood BOD₅ (18). Various types of driers have been used; however, ring driers have been found to be most successful (120).

The economics of blood drying are such that a large volume of blood is required to recover capital and operating costs. The process is energy-intensive and the feed material and product is abrasive and corrosive. Furthermore, expensive air pollution control devices are needed to reduce odours and particulate emissions. Small processors generally must negotiate with a larger local processor with blood drying facilities to handle the blood collected from the kill floor. Independent renderers are often reluctant to collect blood from small processors due to the costs involved and the low profitability of blood drying (121,122). More emphasis needs to be placed on developing markets for dried blood.

Recovery of blood plasma by centrifugation is also becoming more common and increasingly economical. Plasma is used as a binder in sausages and increases the protein content of the product (119). The red cells from centrifugal separation must still be recovered, but removal of plasma reduces the energy requirements for drying and eliminates some of the burning and sticking problems that can develop during drying of whole blood.

A.2.6 Hog Scalding and Dehairing. After killing and bleeding, hogs and sows are scalded and dehaired by a combination of mechanical and manual methods. This normally involves immersion in a steam-heated scald tank followed by abrasive removal of hair in a dehairing machine, singeing and manual polishing of the carcasses. In some plants, the partially dehaired carcass is dipped in a molten rosin depilatory bath prior to mechanical and manual rosin-hair stripping. Sows are easier to dehair than hogs.

Water is used in these operations for filling and makeup water to the scald tank, washing in the mechanical dehairing equipment and lubrication of the carcass to facilitate manual removal of residual hair. Process effluent load can vary considerably

depending on the methods used to remove hair from the kill floor and the methods employed for ultimate disposal of hair. These loads are generally in the range of 0.25 to 1.4 kg BOD₅/1000 kg LWK (18).

In the scald tank, Agriculture Canada regulations require sufficient overflow to prevent undue contamination of the scald water (34). Swift Fresh Meats Co. demonstrated significant water savings by lowering the scald tank water level by 15 cm, without affecting scalding efficiency (115). Such steps also reduce the energy required to maintain scald water temperatures. Slow drainage of scald tanks and separate disposal of the settled concentrated sludges may reduce the waste load associated with dumping of the scald water by 30 percent in terms of BOD₅ and 80 percent in terms of suspended solids (123).

Hair should be handled dry regardless of the ultimate disposal mode. Fluming of hair from the kill floor and subsequent separation by screening will contribute 0.4 kg BOD₅/1000 kg LWK to the total effluent (111).

Dehairing machines generally use large amounts of water to flush hair from the carcass. Screened, recirculated water from a collection tank under the dehairing machine may be adequate at the head-end of the dehairing machine where most of the hair is removed. However, this has not been officially approved by Agriculture Canada.

Final manual polishing of the carcass uses large quantities of water for lubrication. At the Oscar Mayer plant at Beardstown, an automatic switch was installed to shut off the water supply when no hogs were being processed (118). Annual water savings from the \$255 modification were estimated at 6000 m³, equivalent to a reduction in water costs of \$624. More sophisticated equipment could also be used to activate the water supply through water conserving spray nozzles only when a carcass is actually in the wash position.

Equipment has been developed and approved in the United States to skin hogs in a manner similar to that used for beef (124). As yet, this equipment has not been approved for use in Canada (125). Such equipment could reduce the water use, energy costs and waste loads associated with scalding and dehairing, although no comparative data are presently available. Some processors have encountered problems with this equipment in terms of producing as clean a product as that produced by traditional methods (127). Nevertheless, researchers have shown that scalding can contribute to internal contamination through the still-functioning circulatory system, whereas skinning limits contamination to the exposed surfaces of the carcass (127,128,129). Investigations

have also shown that skinning is not deleterious to carcass or belly yields nor to the microbiological quality of the product (130). However, close control is necessary to prevent excessive scoring of bellies which would impair bacon production (131).

A.2.7 Hide Removal and Processing. Hides are removed from beef, normally by mechanical hide pullers, after killing and bleeding. Water use is minimal, but significant quantities of blood and fleshings can enter the sewer system at this point.

Most small meat processors ship hides "green" or packed in salt to tanneries. Larger processors may brine cure hides after recovering fleshings for rendering. On the average, each hide may have 2 kg of manure and mud and 6 kg of fleshings associated with it (132). Brine curing can contribute 1.5 kg BOD₅ per 1000 kg LWK to the process effluent (111).

The fleshings should be recovered for rendering as efficiently as possible. Little can be done to control the discharge of concentrated brine from the curing operation. There has been some experimentation with new curing techniques, including the use of bactericides (132), but these methods are as yet unproven.

A.2.8 Evisceration and Trimming. After hide or hair removal, carcasses are trimmed, split, viscera removed and the post-mortem inspection completed. Hearts, kidneys and livers are saved for edible use; inedible viscera are sent to rendering.

A major contributor to water use in the evisceration stage is sterilization of the viscera table. Agriculture Canada requires cold sprays for removal of blood and extraneous material, and a sterilizing compartment maintained at 82°C (180°F) for moving top tables (133). Viscera table washers can waste excessive amounts of water if not well designed. At the Oscar Mayer plant in Madison, Wisconsin, one viscera line originally using 738 L/min of hot and cold water was modified by the installation of spray nozzles to reduce water usage to 340 L/min (134). Adequate sanitation was maintained at considerable savings in water and energy. Timer-controlled solenoid valves were also used to ensure that the wash system could not be run continuously during the cleanup shift (118). This latter change alone produced an annual saving of \$2900 for a capital investment of \$1300.

Handwashers and organ wash hoses should all be equipped with demand valves, well maintained to ensure proper operation. If space is available, containers should be placed near trimming and eviscerating operations to receive trimmings and other materials. One large American plant incorporated an auger system with numerous

receiving bins to transport all waste materials directly to rendering (135). Less expensive portable containers could be used as effectively.

A.2.9 Beef Viscera Handling. Washing of edible organs such as livers, hearts, and kidneys is the major water use in edible viscera handling. However, the most serious waste disposal problem associated with beef slaughter is the handling of paunch material. The average wet weight of paunch manure per animal is approximately 25 kg. This material has a BOD_5 of approximately 50 000 mg/L, which is 85 percent water soluble (116). The waste load from a plant that sewers paunch manure and washes the paunch for tripe production is 3.5 kg BOD_5 /1000 kg LWK, more than 20 percent of the total process waste load from a packinghouse (111). However, the inventory of the Canadian industry revealed that two percent of the responding plants sewered paunch manure (18).

Paunches may be wet-dumped, dry-dumped, or not dumped. In the wet-dump system, the paunch is opened and paunch manure flushed from the sack with water. Manure is separated from effluent by screening. The paunch can then be sent to rendering or used to produce tripe. This is the most common method used in large plants as it is more efficient at high production rates. Of the large Canadian plants responding to the 1974 inventory, almost 60 percent reported using the wet dump system (18). Wet dumping reduces the organic waste load by approximately 20 percent compared to sewerage of the paunch manure. The explanation for the small reduction in waste load is the high soluble fraction in the paunch material which cannot be removed from the waste stream by physical methods such as screening.

In the dry dump system, the paunch material is emptied from the sack and transported dry to the disposal area. Pressurized blow tanks or dry conveyors are most commonly used. A small amount of water is used to wash the paunch. This procedure results in a 90 percent reduction in the organic waste load compared to wet dumping (111).

In the no-dump system, the paunch sack is transported intact to rendering. Although the waste load associated with paunch handling is virtually eliminated, this procedure does have limitations. Paunch manure in the meat byproduct produced during rendering reduces the protein content of the meal, increases the water content to be removed during drying, discolours the grease, and increases odour problems during rendering. In addition, the potential for production of tripe from the paunch sack is lost (136). However, disposal costs associated with other methods of paunch handling are

eliminated. Few processors use the no-dump system due to the negative economic factors.

Most processors dispose of the paunch manure screened or dry-dumped from the sewer to landfill sites or as fertilizer. However, considerable research and development work has been done to recover a byproduct from paunch manure.

A U.S. EPA funded study found that paunch manure could be dried in a rotary drier. The process could be economical if a market were available for this material as a feed (116). Feeding trials with hogs (116) and catfish (137) have had some success. Feedlot cattle have been successfully fed a ration containing a mixture of dried fresh paunch material and whole blood (138). Other researchers have had some success converting paunch wastes directly to cattle feed (139,140,141). Witherow (136) reviewed alternative paunch handling procedures extensively. Although the production of feed materials from paunch could have potential if a large enough market could be developed, disposal of paunch material as a soil conditioner remains the most feasible solution for Canadian processors.

A.2.10 Intestine Processing. Beef and hog intestines may be sent directly to rendering or they may be hashed and washed prior to being rendered. Hog intestines may be cleaned and saved for sausage casings, 'chitlin' and surgical sutures. Hashing, washing and casing saving can contribute up to 1.2 kg BOD₅/1000 kg LWK to the total plant wasteload (111).

Washers and casing cleaning equipment can be easily modified to reduce water usage and recover slimes. Johnson (142) reported that the use of spray nozzles and pressure control reduced water consumption from 500 L/min to 250 L/min and slime recovery represented a reduction of waste load of 0.1 kg of dry solids per hog.

During the Oscar Mayer study (118), considerable emphasis was placed on modifications to viscera handling equipment. The hasher-washer blades were removed so that the unit functioned as a dewatering device and the intestines were sent intact to rendering. The waste load was reduced by 2.0 kg BOD₅/1000 kg LWK and annual net savings were almost \$130 000. The presence of intestinal material in the rendering process caused some deterioration of grease and a lower selling price. However, the economics were still favourable. Modifications to chitterling washers reduced water use by 50 percent. Spray nozzles were installed in place of shower heads. Annual savings in water represented more than \$5000.

A.2.11 Carcass Washing. Agriculture Canada recommends pressure spray washing equipment for carcass washing. Emphasis is placed on prevention of contamination rather

than removal of contamination during the washing process (133). During the slaughtering of hogs and sows, additional washing of the head and neck area is normally required to remove blood from the area of the stick wounds.

Small plants commonly use a hand-held high pressure hose for final carcass washing. Press-to-open spray valves are normally used to conserve water. In larger processing plants, spray wash cabinets are becoming common due to a lower labour requirement and more time-efficient operation. Large volumes of water under high pressure are used. Removal of some of the nozzles and/or substitution of lower volume nozzles can reduce water use. At Oscar Mayer in Beardstown, Illinois such modification reduced water use from 225 L/min to 115 L/min, an annual saving of \$850 (118).

A control system activating automatic valves only when the carcass is in the washing position can provide considerable savings in spray cabinets. Such modifications contributed significantly to the 50 percent reduction in water consumption achieved by a large Mississippi packer (143).

A.2.12 Meat Processing. Cutting and deboning carcasses is a low water usage operation, producing small waste loads, if properly managed. Trimmings should be recovered in suitable containers as valuable rendering material.

Curing and pickling solutions are major pollutants in meat processing. The chloride content in some complex packinghouse wastes is high. Only approximately 25 percent of the curing brine remains in the product (144).

Meat processing can generate in the range of 5.7 to 6.7 kg BOD₅/1000 kg product (145,146,147). The production of bacon and ham in a pork kitchen produces about 0.75 BOD₅/1000 kg product (18).

Reuse and separate final disposal of curing and pickling solutions is feasible if economics are favourable and alternative disposal options are available. Other means of controlling water and waste from processing operations involve good plant housekeeping. In addition, work at Oscar Mayer in Madison, Wisconsin has shown that flow control valves and temperature regulating flow valves can be effectively utilized in smoke rooms and cooking tanks (126).

A.2.13 Utilities. Although Agriculture Canada regulations are very stringent with regard to reuse of water in edible product contact operations, good quality water from boiler blowdown, compressor cooling jackets and refrigeration condensers can be reused in other areas. As noted previously, utility water has been reused for livestock pen

cleaning (115). Similar schemes could be developed at most plants depending on the processes used, the volume of water required, and the volume available.

Reduction of water use in utility areas is also possible through the use of temperature regulating flow control devices (126). Air-cooled heat exchangers are more efficient in terms of water use than cooling towers or evaporative condensers, although the capital cost may be difficult to recover except in high water cost areas. Once-through cooling water systems are least efficient.

A.2.14 Cleanup and Sanitation. Water and waste management practices relating to cleanup operations in meat and poultry processing are dealt with in detail in Section A.4.

A.3 Water and Waste Management in Rendering Operations

Rendering converts animal byproducts into fats, oils and proteinaceous solids in a variety of cooking and physical separation steps. There are two basic types of rendering:

- Edible rendering, in which fresh, inspected fats and trimmings are cooked for the production of lard and tallow for human consumption.
- Inedible rendering, in which fats, bones, feathers, blood and offal, as well as condemned carcasses and dead stock, are cooked for the production of inedible greases and dry proteinaceous feed materials.

On-site rendering operations handle waste material directly at packinghouses. Almost all edible rendering is done on-site because the raw materials must be fresh. Independent renderers pick up waste materials from slaughter and packinghouses that do not practise on-site rendering, as well as scraps and greases from restaurants, butcher shops and other sources.

Three basic processes are used: wet rendering, low-temperature continuous rendering, and dry rendering.

Wet rendering: Wet rendering is used principally for edible rendering. The animal waste materials are put in a closed tank and cooked with live steam. The water, tallow and solids are separated by settling, filtration, pressing and/or centrifugation. The concentrated water phase, called tank water, is generally used for inedible rendering as it contains a high concentration of proteinaceous matter.

Low-temperature continuous rendering: Low-temperature continuous rendering is a more sophisticated edible rendering process than the traditional wet, batch method. There are three basic continuous rendering systems: the Duke system, the

Carver-Greenfield system and the ANCO-Hormel Strata-Flow system (24). These systems are basically modified batch processes which allow continuous feed and withdrawal. The Carver-Greenfield system is somewhat more sophisticated, utilizing multiple-effect evaporators for the cooking and drying stages.

Dry rendering: Dry rendering is the most commonly used type of inedible rendering process in Canada (18). Like wet rendering, this is basically a batch process in which raw materials are charged to a closed cooker. However, heating is done indirectly through steam jackets until most of the moisture has been evaporated. The tallow and cracklings are separated mechanically.

A.3.1 Water Use in the Rendering Industry. Little Canadian data is available with regard to water use in the rendering industry. The water use associated with on-site rendering operations is difficult to separate from the total packinghouse water use. Few independent renderers responded to the inventory of the Canadian meat and poultry industry. In the four plants which supplied data, the production-based water usage varied 100-fold (18). These data are of little value in estimating water use associated with rendering processes.

Average water use in American surveys of the rendering industry was approximately 3.3 L/kg of raw material, based on data from 47 plants (24). However, the range of water use varied considerably, from 0.5 L/kg to 20 L/kg of raw material.

The major water usage is associated with condensing of cooling vapours, particularly in barometric condensers which are commonly used. The other high water use is plant cleanup.

A.3.2 Waste Loads in the Rendering Industry. The waste load associated with rendering operations is strongly influenced by the rendering process used. In edible rendering processes, tank water is an extremely high-strength waste. The BOD_5 exceeds 30 000 mg/L (24) and sewerage of tank water alone can add 2.0 kg BOD_5 /1000 kg LWK to the effluent load from a slaughtering operation (111). Even if tank water is evaporated in a wet process, up to 50 percent of the protein content will be discharged in the condensate (112).

In dry rendering, the major sources of pollutants are the condensate, which contains in the order of 200 mg/L BOD_5 , and spillage and cleanup (18). Total waste load contribution is approximately 0.5 kg BOD_5 /1000 kg LWK (111).

American surveys have categorized the waste loads associated with independent rendering operation (24). These data are presented in Table A.11.

TABLE A.11 WASTE LOADINGS ASSOCIATED WITH RENDERING OPERATIONS

Parameter	Number of Observations	Loading (kg/1000 kg Raw Material)		
		Average	Maximum	Minimum
BOD ₅	29	2.15	5.83	0.10
Suspended Solids	26	1.13	5.18	0.03
Oil and Grease	18	0.72	4.18	0.00
TKN	17	0.48	1.20	0.12

A.3.2 Water and Waste Management Practices. Little information has been published in technical literature relating to water and waste management practices applicable to rendering operations. Although water use and waste loadings are related to the type of equipment installed in a particular plant, control strategies can minimize inefficient use of water in rendering facilities.

Most modern rendering operations use the low-temperature continuous process rather than the wet batch process. The low-temperature process does not generally provide lower water usage or waste loading than the wet process unless tank water from the wet process is discharged to the sewer (24). However, to control the waste load from wet rendering systems, concentrated tank water should be evaporated and recovered by inedible rendering.

Liquid drainage from the raw material receiving areas can amount to 20 percent of the raw material weight, particularly in rendering plants handling wastes from poultry processing operations (24). Loss of this material to the sewer reduces the net yield from the process, as well as contributing a high strength waste discharge. If this drainage can be contained, it can be recovered in the cookers. Alternatively, an American plant steam sparges the isolated drainage liquid and recovers the solid material by screening (24). This system reduces the moisture load on the cookers.

Total water use in a rendering plant is most strongly influenced by the type of condenser used for condensing cooking vapours. Of the three available methods - barometric condensers, shell and tube exchangers, and air-cooled condensers - barometric condensers use at least twice as much water (24). However, some auxiliary odour control equipment is usually required with the latter two systems. If a water scrubber is used, the water usage associated with the process will increase.

It is becoming common practice to use treated wastewaters in barometric condensers (148,149,150). Effluent from biological treatment processes or well-operated air flotation cells will provide water of adequate quality, reducing the potable water requirements.

The waste load from the condensers can be controlled by (24):

- avoiding overloading cookers,
- providing and maintaining traps in the vapour lines,
- controlling the speed of agitation,
- providing by-pass valves to control pressure bleed-down on cookers used to hydrolyze raw material,
- controlling cooking rate.

A.4 Cleaning and Sanitizing in the Meat and Poultry Industry

Cleaning and sanitizing practices are similar in the meat and poultry processing industries. Cleanup operations include the removal of solids and accumulated blood from the kill area during breaks, and thorough cleaning and sanitizing of the facilities at the end of the production shift. Similar equipment and procedures are used, and comparable results can be obtained from similar waste and waste management programs. This review of management practices in cleaning operations is also applicable to the rendering industry, although the requirements for sanitation in off-site inedible rendering establishments are not as rigid.

A.4.1 Water Use in Cleanup Operations. Water usage during cleanup operations is most significantly influenced by the procedures used in a particular plant and the physical size of the plant. In any one facility, the daily water use associated with cleanup is relatively constant and independent of the daily production rate.

Little information is available regarding the quantities of water used in cleanup operations because of the great variation between plants. During baseline data collection at the Gold Kist poultry plant, cleanup after the kill shift was found to represent approximately 13 percent of the total plant water usage (14). In the hog slaughtering operation at the Oscar Mayer plant, Madison, Wisconsin, after-kill cleanup contributed approximately 30 percent of the total water usage (118). Typically, between 15 and 30 percent of the total plant water usage is associated with cleaning operations. A comparable figure has been cited for rendering operations (24).

A.4.2 Waste Loads in Cleanup Operations. The waste loads associated with cleanup depend on the intensity of dry cleanup practised in the plant. Wet cleanup operations wash large quantities of solids, grease and blood to the sewer. These materials can be removed dry prior to final washdown of floors and equipment.

In the poultry industry, published data indicates that wet cleanup can contribute up to 4.5 kg BOD₅/1000 broilers to the waste load, compared to 1.8 kg BOD₅/1000 birds at plants practising dry cleanup (112).

Similarly, in red meat processing, the waste load from cleaning operations can range from approximately 0.3 kg/1000 kg LWK in plants using dry procedures to 3.0 kg/1000 kg LWK in plants using wet procedures (151).

The waste load associated with cleanup operations in rendering facilities may be as much as 43 percent of the total effluent BOD₅ and 50 percent of the total effluent suspended solids (24).

A.4.3 Water and Waste Management Practices. Although cleanup operations may represent less than 25 percent of the total plant effluent flow and waste loading, considerable improvement can be made in water use efficiency through simple management programs. In most cases, high water use is associated with poorly managed cleanup staff using large volumes of low-pressure water to flush waste materials to the drains. An employee education program combined with close surveillance during cleanup will eliminate many of these wasteful water use practices.

Most meat and poultry processors in Canada practise some degree of dry cleanup prior to plant washdown. According to the inventory of Canadian plants (18), 83 percent of red meat processors and 85 percent of poultry processors use dry cleanup procedures. In most cases, these dry cleaning routines have been instituted to recover meat scraps as byproducts for rendering rather than to reduce water use and waste loadings. Although the dry removal of gross solids will reduce the effluent BOD loading associated with cleanup by approximately 50 percent, more intensive dry cleaning prior to a final low-volume, high-pressure rinse of floors and equipment can produce a further six-fold reduction in the waste load in meat packing plants (151).

During the waste management studies at the Gold Kist poultry plant (14), the cleanup shift was identified as an area of excessive water use. Water was used to "sweep" the floor and hoses were left running when not in use. To improve water use practices, ball valves were installed on the cleanup hoses so that the flow of water could be easily shut-off when the hose was not in use. Open-ended hoses were fitted with nozzles to

restrict the flow and improve the flow distribution pattern. It was also found that the installation of water meters on cleanup hoses had the psychological effect of reminding cleanup personnel of the need to conserve water. However, the education of the shift foreman made the greatest effect. Although a foreman with several months experience and training could consistently reduce water use during cleanup by 50 percent, a new cleanup foreman inevitably resulted in an increase in water usage.

At Oscar Mayer (118), an industrial vacuum cleaner was evaluated as a possible means of improving dry cleanup. Although the unit effectively removed blood, scraps and bonedust from the floor area, it was cumbersome and slow. Basic tools such as brooms, shovels and drums are equally effective and less time-consuming in most instances.

Enforcing dry cleanup procedures throughout a plant can be time-consuming because it must be done on a continuous basis to be effective. The degree of dry cleanup required should be decided on an economic basis by comparing the labour and supervisory costs against the water and waste disposal costs at the specific plant. In most instances, it is more cost-effective to minimize the quantity of waste materials which accumulate on the floor by providing well-placed containers to receive trimmings and viscera.

A variety of high-pressure, low-volume cleaning equipment is available from a number of suppliers, as outlined in Appendix B. Both portable equipment and centralized systems with outlets throughout the plant are included. These high-pressure systems can be used with hot or cold water and in conjunction with a variety of sanitizing agents. A number of these systems and many sanitizing compounds have been approved for use in Canadian meat and poultry processing establishments (125).

These high-pressure systems operate at pressures up to 5000 kPa and delivery rates of 9 to 18 L/min (152,153). In addition to the reduction in water use and improved cleaning efficiency, an estimated 70 percent improvement in cleaning time has been claimed compared to traditional methods (153). High-pressure (5000 kPa), low-volume (14 L/min) equipment using cold water (10°C) has been shown to be as effective for cleaning surfaces in abattoirs as low-pressure (550 kPa), high-volume (45 to 70 L/min) systems using hot water (65.6 to 82.2°C) (154). However, current Canadian regulations for cleaning in meat and poultry processing establishments require water at a minimum temperature of 82°C (155).

Automated CIP cleaning systems are routinely used in the dairy industry and are becoming more common in the meat products industry (156,157,158). These systems

automatically control water temperature, flow rate, and chemical addition, and recirculate cleaning solutions, resulting in significant savings in water, energy and cleaning chemicals. A system recently installed by an American processor to clean and sanitize eight smokehouses has been estimated to save almost \$25 000 annually in chemicals alone (156). Such systems could equally well be used for cleaning and sanitizing viscera pans, tank trucks, continuous rendering systems, conveyor tables, piping, cookers and driers, with considerable savings in water, labour, energy and chemicals (123).

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APPENDIX B

LIST OF EQUIPMENT SUPPLIERS

APPENDIX B

LIST OF EQUIPMENT SUPPLIERS

This equipment suppliers list contains some of the inexpensive items used during the demonstration studies, as well as higher-cost equipment available for major in-plant modifications. The listing is not intended to include all suppliers of various equipment; however, it provides plant personnel initiating a water and waste management program with some indication of possible sources of equipment.

B.1 Equipment Used in Demonstration Studies

Equipment	Type	Supplier
1) Flow Meters	Trident Cumulative Use	Neptune Meters Ltd. Toronto, Ontario
	Hedland In-Line Flowmeter	Brian Engineering Ltd. Kitchener, Ontario
2) Spray Nozzles and Accessories	Spraying Systems Co. Variety of nozzle types and fittings.	John Brooks Canada Ltd. Mississauga, Ontario Calgary, Alberta
3) Plastic Tanks	82-Litre Cylindrical	Plastics Canada Toronto, Ontario
	2270-Litre Rectangular	Rosedale Plastics Ltd. Markham, Ontario
4) Pumps	Atlas-Monarch Centrifugal	Atlas Engineering and Machine Co. Toronto, Ontario
	Wilden M-8 Double Diaphragm Pump	York Fluid Controls Ltd. Weston, Ontario
	Watts SB1 1/2-8 Air Vacuum Pump	Oliver Industrial Supply Ltd., Calgary, Alberta
5) Level Control Switch	Flygt	Flygt Canada Ltd. Rexdale, Ontario

Equipment	Type	Supplier
6) Valves	Demand Flow Handwash Station	Simon Johnson Food Equipment Ltd. St. Thomas, Ontario
	"Water-Miser" Handwash Valve	Canadian Bird Equipment Ltd. Hamilton, Ontario
	36 Valves, Spraying Systems Co.	John Brooks Canada Ltd. Mississauga, Ontario Calgary, Alberta
	Solenoid Valves (ASCO)	Conval Equipment Ltd. Toronto, Ontario
	Ball Valves	ITT Grinnel Toronto, Ontario
		Plastics Canada Toronto, Ontario
	Dole Flow Controls	Crane Canada Ltd. Calgary, Alberta
	Flow Control Valves	Dresser Industries Cambridge, Ontario
	Butterfly Valves	Miller Plastics Toronto, Ontario
	Strahman M-70 Water Saver Nozzles	Cantech Controls Ltd. Toronto, Ontario
	Foot Operated Valve	Crane Canada Ltd. Toronto, Ontario
7) Pipe, Hose and Fittings	Korotron Braided Tubing	Plastics Canada Ltd. Toronto, Ontario
	Rubber Food Hose	ABC Rubber Co. Mississauga, Ontario
	Misc. Plastic Pipe and Fittings	Plastics Canada Ltd. Toronto, Ontario
	Misc. Pipe and Fittings	Crane Canada Ltd. Calgary, Alberta Western Supplies Ltd. Calgary, Alberta
8) Timer	Intermatic V47171	Union Electric Supply Co. Mississauga, Ontario

Equipment	Type	Supplier
9) Limit Switch	Type B54J	John L. Robertson Co. Ltd. Mississauga, Ontario
10) Stainless Steel and Other Metals	Type 304	Atlas Alloys Etobicoke, Ontario
	Misc. Metals	Inland Metals Calgary, Alberta

B.2 Major Equipment Suppliers

Equipment	Suppliers
1) Dry (Poultry) Offal Conveyance Systems	Stork Werkspoor Canada Ltd. Lachine, Quebec Simon-Johnson Food Equipment Ltd. St. Thomas, Ontario Barker International, Inc. Marietta, Georgia
2) Dry Conveyance System (suitable for poultry and red meat viscera, feathers, blood, paunch manure, etc.).	American Billdal Corporation (Representatives for Tor, Palmia) Glenview, Illinois
3) Plate Heat Exchangers (suitable for chillers and scalders)	APV-Crepaco of Canada Ltd. Weston, Ontario
4) High Pressure Red Meat Carcass Washing Equipment	Chad, Inc. Kansas City, Kansas

Equipment	Suppliers
5) High Pressure Cleaning and Sanitizing Equipment	Ranchers' Supplies Co. Ltd. Weston, Ontario Nortech Control Equipment Inc. Toronto, Ontario Graco, Inc. Mississauga, Ontario Sanfax Industries Ltd. Dorval, Quebec Dixie Chemicals and Packaging Ltd. Mississauga, Ontario
6) Hog Hide Puller	Cincinnati Butchers Supply Cincinnati, Ohio
7) Spray Scalders (poultry)	Simon-Johnson, Inc. Kansas City, Missouri
8) Microwave Scalders	Beehive Machinery Company Salt Lake City, Utah Corbett Enterprises Inc. Gainesville, Georgia

APPENDIX C

SUMMARY OF CANADIAN WATER AND SEWER RATES AND SURCHARGE FORMULAE

1. Town of Aurora

(i) Water Rate: \$0.48 per 1 100 Imperial gallons per month

(ii) Sewer Service Rate Schedule:

<u>Consumption (Igal/month)</u>	<u>Rate (\$/1000 Igal/month)</u>
less than 50 000	\$0.25
50 000 to 250 000	\$0.20
greater than 250 000	\$0.18

(iii) Surcharge Formula: None in effect

(iv) By-law Limits:

BOD ₅	=	500 mg/L
Suspended Solids	=	600 mg/L
Oil and Grease	=	100 mg/L

2. City of Brandon

(i) Water Rate Schedule:

<u>Quarterly Consumption (ft³)</u>	<u>Rate (\$/100 ft³/3 months)</u>
less than 5 000	\$0.75
5 000 to 100 000	\$0.60
greater than 100 000	\$0.45

(ii) Sewer Rate Schedule:

<u>Quarterly Consumption (ft³)</u>	<u>Rate (\$/100 ft³/3 months)</u>
0 to 100 000	\$0.35
greater than 100 000	\$0.20

(iii) Additional charge for meatpacking and similar companies: \$0.44/100 ft³
(currently under review)

3. City of Brantford

(i) Water Rate Schedule:

- | | <u>Bimonthly Consumption (ft³)</u> | <u>Rate (¢/100 ft³)</u> |
|--|---|------------------------------------|
| | greater than 7 200 | 38.1¢ |
| | next 52 800 | 29.3¢ |
| | balance | 24.0¢ |
- (ii) Sewer Rate: 85% of Water Consumption Charge
- (iii) Surcharge Formula:
- (a) Surcharge (\$ per two months) = $x V_b + y V_s$
 where:
- x = cost per kilogram for treatment of BOD₅ (\$0.1454)
 y = cost per kilogram for treatment of suspended solids (\$0.0611)
 V_b = excess kilograms of BOD₅ per two month period
 V_s = excess kilograms of suspended solids per two month period
- (b) Surcharge (\$ per two months) = $z V_d + y V_s$
 where:
- z = cost per kilogram for treatment of COD (\$0.0493)
 V_d = excess kilograms of COD per two month period
 y, V_s are as defined in (a)
- (iv) By-law Limits:
- | | | |
|------------------|---|-----------|
| BOD ₅ | = | 300 mg/L |
| Suspended Solids | = | 350 mg/L |
| COD | = | 1000 mg/L |
| Oil and Grease | = | 100 mg/L |

4. City of Calgary

- (i) Water Rate Schedule:

<u>Consumption (m³/month)</u>	<u>Rate (\$/m³)</u>	
	<u>Within City</u>	<u>Outside City</u>
less than 23	\$0.2639	\$0.3155
23 to 46	\$0.2399	\$0.2873
46 to 137	\$0.2135	\$0.2543
137 to 273	\$0.1728	\$0.2073
273 to 682	\$0.1199	\$0.1413

682 to 2 273	\$0.1079	\$0.1296
greater than 2 273	\$0.0911	\$0.1083

(ii) Sewer Service Charges: 80% of total water bill

(iii) Surcharge Formula:

$$R (\text{¢/m}^3) = .0112B + .0125S + .0129G$$

where:

B = concentration (mg/L) BOD₅ in excess of limit

S = concentration (mg/L) suspended solids in excess of limit

G = concentration (mg/L) oil and grease in excess of limit

(iv) By-law Limits:

BOD₅ = 300 mg/L

Suspended Solids = 300 mg/L

Oil and Grease = 100 mg/L

5. City of Charlottetown

(i) Water and Sewer Rate: \$0.73 per 1000 Imperial Gallons

(ii) Surcharge Formula:

$$\begin{aligned} \text{Surcharge (¢/1000 Igal)} = & \frac{SS (\text{ppm}) - 350}{350} \times 4.8 \\ & + \frac{GR (\text{ppm}) - 100}{100} \times 4.8 \end{aligned}$$

where: SS = concentration of suspended solids

GR = concentration of grease

(iii) By-law Limits:

BOD₅ = 300 mg/L

6. City of Corner Brook

(i) Water Rate Schedule:

<u>Consumption (Igal per month)</u>	<u>Rate (\$/1000 Igal)</u>
-------------------------------------	----------------------------

less than 2 000 000	\$0.40
---------------------	--------

greater than 2 000 000	\$0.20
------------------------	--------

(ii) Sewer and Surcharge Rates: None in effect

7. Regional Municipality of Durham

(i) Water Rate Schedule (1980):

<u>Quantity (Igal/month)</u>	<u>Rate (\$/1000 Igal)</u>
less than 10 000	\$0.782
10 000 to 1 000 000	\$0.520
greater than 1 000 000	\$0.361

(ii) Sewer Rate Schedule (1980):

<u>Quantity (Igal/month)</u>	<u>Rate (\$/1000 Igal)</u>
less than 10 000	\$1.351
10 000 to 1 000 000	\$0.920
greater than 1 000 000	\$0.658

(iii) Surcharge Formula:

$$\text{Annual Surcharge } \$ = F \times 10^{-5} \times (\text{BOD}-500) O_{\text{BOD}} + (\text{SS}-600) O_{\text{SS}}$$

where:

F	=	total flow in Imperial gallons
BOD	=	average BOD ₅ (mg/L)
SS	=	average suspended solids (mg/L)
O_{BOD}	=	cost to treat one pound of BOD ₅ (\$0.10 in 1978)
O_{SS}	=	cost to treat one pound of suspended solids (\$0.10 in 1978)

(iv) By-law Limits:

BOD ₅	=	500 mg/L
Suspended Solids	=	600 mg/L
Oil and Grease	=	100 mg/L

8. City of Edmonton

(i) Water Rate Schedule:

<u>Monthly Consumption (m³)</u>	<u>Rate (\$/m³)</u>	
	<u>In City</u>	<u>Suburban</u>
less than 22.7	\$0.388	\$0.448
22.7 to 113.3	\$0.311	\$0.357
113.3 to 707.9	\$0.240	\$0.277

707.9 to 14 148.3	\$0.205	\$0.236
greater than 14 158.3	\$0.166	\$0.222

(ii) Sewer Rate Schedule - Commercial/Industrial Customers:

<u>Monthly Consumption (m³)</u>	<u>Rate (\$/m³)</u>
less than 14 158.3	\$0.154
greater than 14 158.3	\$0.102

(iii) Surcharge Rate Schedule:

<u>Pollutant</u>	<u>Cost per Pound in Excess of Limit</u>
BOD ₅	\$.0163
Suspended Solids	\$.00523
Oil and Grease	\$.00697

(iv) By-law Limits:

BOD ₅	=	700 mg/L
Suspended solids	=	400 mg/L
Oil and Grease	=	200 mg/L

9. City of Halifax

(i) Water Rate Schedule:

<u>Consumption (Igal per Quarter)</u>	<u>Rate (\$/1000 Igal)</u>
less than 3 000 000	\$0.64
greater than 3 000 000	\$0.39

(ii) Sewer and Surcharge Rates: None in effect

10. Ville de Hull

(i) Water Rate: \$0.60/1000 Igal

(ii) Sewer and Surcharge Rates: None in effect

11. Regional Municipality of Halton

(i) Water Rate Schedule:

<u>Consumption (m³/month)</u>	<u>Rate(¢/m³)</u>
0 to 13.64	No consumption rate
next 895.45	9.90¢
balance	6.60¢

(ii) Sewer Rate: 170 percent of the water consumption charge (subject to approval)

(iii) Surcharge Formula:

$$\text{Surcharge (\$/month)} = F \times Q \times R$$

where:

$$F = \frac{\text{Actual Strength} - \text{Allowable Strength}}{\text{Allowable Strength}}$$

for whichever parameter is greatest in excess of the by-law limits

$$Q = \text{monthly volume in millions of gallons}$$

$$R = \text{rate for sewage treatment in \$/million gallons (Rate R varies from \$500 to \$1000 per million gallons depending on the particular WPCP handling the discharge).}$$

(iv) By-law Limits:

$$\text{BOD}_5 = 300 \text{ mg/L}$$

$$\text{Suspended Solids} = 350 \text{ mg/L}$$

$$\text{Oil and Grease} = 100 \text{ mg/L}$$

12. City of Lethbridge

(i) Commercial/Industry Water Rate Schedule:

<u>Meter Size</u>	<u>Bimonthly Minimum (less than 1001 ft³)</u>
3-inch	\$26.31
4-inch	\$35.22
6-inch	\$56.44
8-inch	\$99.59

<u>Bimonthly Consumption (ft³)</u>	<u>Rate (\$/100 ft³)</u>
1 001 to 5 000	\$0.58
5 001 to 50 000	\$0.45
50 001 to 200 000	\$0.31
greater than 200 000	\$0.28

(ii) Industrial Sewer Service Charge:

$$\text{Service Charge (\$)} = 0.4C_c \frac{V_i}{V_c} + 0.3C_c \frac{B_i}{B_c} + 0.3C_c \frac{S_i}{S_c}$$

where:

- C_c = total capital, interest and operating cost expressed in dollars that is incurred by the City in treating sewage over the three calendar months period
- V_c = total volume of sewage expressed in cubic feet that the City has received for treatment over the same three calendar months period
- V_i = total volume of sewage expressed in cubic feet that the industry discharges into the City sewerage system over the same three calendar month period
- B_i = total weight of biochemical oxygen demand expressed in pounds that the industry discharges into the City sewerage system over the same three calendar months period
- B_c = total weight of biochemical oxygen demand expressed in pounds that the City has received for treatment over the same three calendar months period
- S_i = total weight of suspended solids expressed in pounds that the industry discharges into the City sewerage system over the same three calendar month period
- S_c = total weight of suspended solids expressed in pounds that the City has received for treatment over the same three calendar months period

in 1978, C_c ranged from about \$200 000 to \$265 000.

Note: Each plant's sewage flow is metered.

(iii) Surcharge Formula:

Surcharge = 0.5 times the quarterly service charge for each day that one or more of the parameter limits is exceeded, e.g., if plant X pays a quarterly service charge of \$20 000 and the BOD₅ and/or SS and/or O&G limits are exceeded for one day, a surcharge of

\$10 000 is imposed; if a limit is exceeded on two days during the quarter, the surcharge is \$20 000.

Surcharges are banked separately, and held for three years. They may be rebated if the plant significantly improves its waste treatment. If not, the money goes to the City after three years.

(iv) By-law Limits:

After 1 October 1977:

BOD ₅	=	600 mg/L
Suspended Solids	=	600 mg/L
Oil and Grease	=	200 mg/L

After 1 October 1979:

BOD ₅	=	300 mg/L
Suspended Solids	=	300 mg/L
Oil and Grease	=	100 mg/L

13. City of London

(i) Water and Sewer Rate Schedule:

<u>Bimonthly Consumption (ft³)</u>	<u>Rate (\$/100 ft³)</u>
less than 200	\$2.50
200 to 50 000	\$0.480
greater than 50 000	\$0.338

(ii) Surcharge Formula:

$$\text{Annual Surcharge (\$/1000 lgal)} = f_b \left[\left(\frac{Bi - Bm}{Bm} \right) \right] + f_s \left(\frac{Si - Sm}{Sm} \right) \left[\frac{To}{100} \right]$$

where:

f_b	=	proportion of cost allocated to reducing BOD ₅ = 0.5
f_s	=	proportion of cost allocated to reducing SS = 0.5
Bi	=	effluent BOD ₅ (mg/L)
Si	=	effluent SS (mg/L)
Bm	=	by-law limit on BOD ₅ (mg/L)
Sm	=	by-law limit on SS (mg/L)
To	=	cost (¢/1000 lgal) of sewage treatment plant operation (1977 = 23.06¢)

(iii) By-law Limits:

BOD₅ = 300 mg/L

Suspended Solids = 350 mg/L

14. City of Moncton

(i) Water Rate Schedule:

<u>Quantity (Igal)</u>	<u>Rate (¢/1000 Igal)</u>
less than 300 000	58¢
300 000 to 600 000	50¢
greater than 600 000	36¢

(ii) Sewer and Surcharge Rates: None in Effect

15. Regional Municipality of Niagara

(i) Water Rate: Wholesaled to municipalities at \$0.321/1000 Igal.

(ii) Sewer Rate: Not available

(iii) Surcharge Formula:

$$\text{Surcharge (\$)} = V \times F (0.5 B + 0.55) C$$

where:

V = volume of sewage in Imperial gallons

F = 10^{-5} B = concentration of BOD₅ (mg/L)

S = concentration of suspended solids (mg/L)

C = cost in dollars per pound for treating sewage (1975 = \$0.08)

(iv) By-law Limits:

BOD₅ = 500 mg/L

Suspended Solids = 500 mg/L

Oil and Grease = 100 mg/L

16. Regional Municipality of Peel

(i) Water Rate Schedule:

<u>Consumption (Igal/month)</u>	<u>Rate (\$/1000 Igal)</u>
less than 100 000	\$0.87
100 000 to 1 000 000	\$0.83
greater than 1 000 000	\$0.79

(ii) Sewer Rate Schedule:

<u>Consumption (Igal/month)</u>	<u>Rate (\$/1000 Igal)</u>
less than 100 000	\$1.00
100 000 to 1 000 000	\$0.92
greater than 1 000 000	\$0.84

(iii) Surcharge Formula:

$$\text{Annual Surcharge (\$)} = F \times Q \times R$$

where:

$$F = \frac{\text{actual strength} - \text{allowable strength}}{\text{allowable strength}}$$

for grease, BOD₅, suspended solids or other constituents, whichever is greatest in excess of the respective by-law limits

$$Q = \text{annual volume in million Imperial gallons}$$

$$R = \text{rate for sewage treatment in \$ per million gallons (1979 = \$535)}$$

(iv) By-law Limits:

$$\text{BOD}_5 = 500 \text{ mg/L}$$

$$\text{Suspended Solids} = 600 \text{ mg/L}$$

$$\text{Oil and Grease} = 150 \text{ mg/L}$$

17. City of Regina

(i) Water Service Rate Schedule:

\$7.00 minimum, up to 1000 ft³ for a two month period
 \$0.70/100 ft³ for all metered consumption over 1000 ft³

(ii) Sewer Rate Schedule:

\$7.25 minimum, up to 1000 ft³ for a two month period
 \$0.78/100 ft³ for all metered consumption over 1000 ft³

(iii) Surcharge Formula:

$$R = (w \times B) + (\bar{x} \times S) + (y \times G) + (z \times P)$$

where:

$$R = \text{¢/100 ft}^3$$

$$w = 0.031$$

$$\bar{x} = 0.031$$

$$y = 0.027$$

$$z = 0.060$$

$$B = \text{mg/L BOD}_5 \text{ in excess of limit}$$

$$S = \text{mg/L suspended solids in excess of limit}$$

$$G = \text{mg/L oil and grease in excess of limit}$$

$$P = \text{mg/L phosphorus in excess of limit (expressed as phosphates)}$$

(iv) By-law Limits:

$$\text{BOD}_5 = 300 \text{ mg/L}$$

$$\text{Suspended Solids} = 300 \text{ mg/L}$$

$$\text{Oil and Grease} = 100 \text{ mg/L}$$

$$\text{Phosphorus} = 30 \text{ mg/L}$$

18. City of Saint John

(i) Water Rate Schedule:

<u>Consumption (Igal/month)</u>	<u>Rate (\$/1000 Igal)</u>
less than 50 000	\$0.47
50 000 to 450 000	\$0.36
450 000 to 4 500 000	\$0.29
4 500 000 to 45 000 000	\$0.18
greater than 50 000 000	\$0.10

(ii) Sewer Rate: 99 percent of water service bill

(iii) Surcharge Formula: None in effect

(iv) By-law Limits:

BOD ₅	=	400 mg/L
Suspended Solids	=	400 mg/L
Oil and Grease	=	150 mg/L

19. City of Saskatoon

(i) Water Rate Schedule:

<u>Consumption (ft³/month)</u>	<u>Rate (\$/100 ft³)</u>
less than 1 000	\$0.66
1 000 to 3 000	\$0.55
3 000 to 13 000	\$0.48
13 000 to 75 000	\$0.37

(ii) Sewer Rate Schedule:

<u>Consumption (ft³/month)</u>	<u>Rate (\$/100 ft³)</u>
less than 13 000	\$0.36
13 000 to 75 000	\$0.335
greater than 75 000	\$0.26

(iii) Surcharge Formula:

$$R = A \left(1 + \frac{x}{300} \right) + B \left(1 + \frac{y}{300} \right) + C \left(1 + \frac{z}{100} \right)$$

where:

$$R = \text{¢/100 ft}^3$$

$$A = 2.7\text{¢/100 ft}^3$$

$$B = 4.7\text{¢/100 ft}^3$$

$$C = 2\text{¢/100 ft}^3$$

$$x = \text{mg/L BOD}_5 \text{ in excess of limit}$$

$$y = \text{mg/L suspended solids in excess of limit}$$

$$z = \text{mg/L oil and grease in excess of limit}$$

(iv) By-law Limits:

BOD ₅	=	300 mg/L
Suspended Solids	=	300 mg/L
Oil and Grease	=	100 mg/L

20. Regional Municipality of Sudbury

(i) Water Rate: \$0.52 per 1000 Imperial gallons

(ii) Sewer and Surcharge Rates: None in effect

(iii) By-law Limits:

BOD₅ = 500 mg/L

Suspended Solids = 350 mg/L

Oil and Grease = 150 mg/L

21. Town of Summerside

(i) Water and Sewer Rate: \$0.88 per 1000 Imperial Gallons

(ii) Surcharge Formula:

$$\text{Surcharge (¢/1 000 Igal)} = \frac{\text{SS (ppm)} - 350}{350} \times 5.3 + \frac{\text{GR (ppm)} - 100}{100} \times 5.3$$

where:

SS = concentration of suspended solids

GR = concentration of grease

(iii) By-law Limits:

BOD₅ = 300 mg/L22. Municipality of Metropolitan Toronto

(i) Basic Water and Sewer Rates: \$0.966 per 1000 Imperial gallons

(ii) Sewer Service Charge: 13% of basic water and sewer rate

(iii) Surcharge Formula:

$$\text{Annual Surcharge (\$)} = V \times F \times G \times C$$

where:

V = Annual plant discharge (Igal)

F = 10^{-5} G = excessive concentration of SS, Grease, BOD₅ or Phenol in mg/L, whichever is greatest in excess of the respective by-law limits

C = cost in \$ for treating excessive waste strength (1979 = \$0.035/lb)

(iv) By-law Limits:

BOD ₅	=	500 mg/L
Suspended Solids	=	600 mg/L
Oil and Grease	=	150 mg/L
Phenols	=	1 mg/L

23. City of Vancouver

(i) Water Rate Schedule:

Consumption (100 ft³)

<u>Two Month Period</u>	<u>Four Month Period</u>	<u>Rate per 100 ft³ unit</u>
Less than 200	Less than 400	\$0.301
200 to 600	400 to 1 200	\$0.242
600 to 1 600	1 200 to 3 200	\$0.188
greater than 1 600	greater than 3 200	\$0.168

(ii) Sewer and Surcharge Rates: None in effect

(iii) By-law Limits:

Suspended Solids	=	600 mg/L
Oil and Grease	=	150 mg/L

24. Regional Municipality of Waterloo

(i) Water and Sewer Rate Schedule:

<u>Serviced Area</u>	<u>Quantity (Igal)</u>	<u>Water Rate (¢/1000 Igal)</u>	<u>Sewer Rate (¢/1000 Igal)</u>
Kitchener	less than 3 117	85.02¢	63.76¢
	3 117 to 121 563	70.58¢	52.94¢
	next 187 020	64.16¢	48.12¢
	balance	59.35¢	44.51¢
Waterloo	all	52.94¢	52.94¢
Cambridge	less than 74 808	62.88¢	44.02¢
	balance	51.33¢	35.93¢
Woolwich	less than 623.4	64.16¢	48.12¢
	next 3 740.4	48.12¢	48.12¢
	balance	32.08¢	48.12¢
St. Jacobs	all	80.¢	117.¢
New Hamburg	less than 20 000	40.¢	28.¢
	balance	30.¢	21.¢
Baden	all	50.¢	110.¢

(ii) Surcharge Formula:

$$\text{Surcharge } (\text{¢}) = Q \left[f_s \left(\frac{S_i - S_n}{S_n} \right) + f_p \left(\frac{P_i - P_n}{P_n} \right) \right] R_n$$

where:

Q = quantity of sewage in 1000 Igal

f_s = proportion of cost allocated to reducing suspended solids = 0.5

f_p = proportion of cost allocated to reducing BOD_5 = 0.5

S_i = suspended solids concentration (mg/L)

P_i = BOD_5 concentration (mg/L)

S_n = By-law limit on suspended solids

P_n = By-law limit on BOD_5

R_n = operating costs of sewage treatment plants in ¢/1000 Igal as follows:

Kitchener = 15.22¢

Waterloo = 15.75¢

Cambridge = 21.29¢

Wilmot = 31.89¢

Woolwich = 28.98¢

(iii) By-law Limits:

BOD_5 = 300 mg/L

Suspended Solids = 350 mg/L

Oil and Grease = 100 mg/L

25. City of Windsor

(i) Water Rate: \$0.19 per 100 cubic feet

(ii) Sewer Rate: None in effect

(iii) Surcharge Formula:

$$\text{Surcharge } (\$/1000 \text{ Imperial Gallons}) = 1000 \times F \times E \times C$$

where:

F = factor converting mg/L to pounds per gallon

E = excessive concentration of BOD_5 , suspended solids or grease (whichever is higher) above by-law limits

C = cost of treatment (7.7¢ per pound)

(iv) By-law Limits:

BOD ₅	=	500 mg/L
Suspended Solids	=	600 mg/L
Oil and Grease	=	150 mg/L

26. City of Winnipeg

(i) Water Rate Schedule:

<u>Quarterly Consumption (ft³/3 months)</u>	<u>Rate (\$/100 ft³/3 months)</u>
less than 9 600	\$0.72
9 600 to 96 000	\$0.47
greater than 96 000	\$0.34

(ii) Sewer Rate Schedule:

<u>Quarterly Consumption (ft³/3 months)</u>	<u>Rate (\$/100 ft³/3 months)</u>
less than 9 600	\$0.415
9 600 to 96 000	\$0.415
greater than 96 000	\$0.415

(iii) Surcharge Formula:

Quarterly Surcharge (¢/1000 lgal) =

$$\left[f_s \left(\frac{S_i - S_n}{S_n} \right) + f_p \left(\frac{P_i - P_n}{P_n} \right) \right] R_n + \left(\frac{C_i - C_n}{C_n} \right) R_c + \left(\frac{X_i - X_n}{X_n} \right) R_x$$

where:

- f_s = factor derived from costs of reducing solids; varies from year to year (0.50 in 1979)
- f_p = factor derived from costs of reducing BOD₅; varies from year to year (0.50 in 1979)
- S_i = suspended solids in the industrial waste (ppm)
- P_i = BOD₅ in the industrial waste (ppm)
- C_i = chlorine demand in the industrial waste (ppm)
- X_i = substance requiring additional treatment in the industrial waste

- P_n = BOD_5 in the municipal sewage serving as base or normal (ppm)
 S_n = suspended solids in the municipal sewage serving as base or normal (ppm)
 C_n = chlorine requirement in the municipal sewage serving as base or normal (ppm)
 X_n = substance requiring additional treatment in municipal sewage serving as base or normal (ppm)
 R_n = unit charge based on cost of treating
 R_x = unit charges based on cost of treating any substance requiring additional treatment
 R_c = unit charge based on cost of required chlorine (4 in 1979)

(iv)

By-law Limits:

- BOD_5 = 300 mg/L
 Suspended Solids = 350 mg/L

APPENDIX D

METRIC CONVERSIONS

APPENDIX D**METRIC CONVERSIONS**

centimetre	(cm)	=	inches x 2.54	
cubic metre	(m ³)	=	L x 0.001	
		=	Igal x 0.004546	
kilogram	(kg)	=	lb x 0.454	
kilopascal	(kPa)	=	psi x 6.895	
		=	psi x 0.0703	= kg/cm ²
litre	(L)	=	Igal x 4.546	
		=	U.S. gal x 3.7853	
metric tonne	(t)	=	ton (short) x 0.907	

Canada